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Should Smallholder Oil Palm Farmers Grow Commodity with Higher Carbon Sequestration? Evaluating the Voluntary Carbon Market Potential in Indonesia

Abstract

Oil palm is one of the most popular commodities for smallholder farmers, especially in Indonesia. Given the development of the voluntary carbon market, there are opportunity for oil palm farmers to perform financially better by shifting to other commodities that have higher carbon revenue potential. The aim of this research is to find alternative commodities that could outperform oil palm plantation for smallholder farmers in Indonesia, with the addition of carbon revenue.

The Small-Holder Agriculture Monitoring and Baseline Assessment (SHAMBA) methods from plan vivo foundation suits this purpose for gaining additional revenue on top of the commodity sales in the form of carbon credit compensation. The SHAMBA methods, compensates smallholder farmers that grow crops with high carbon sequestration. Some of the potential alternative commodity with higher carbon sequestration than oil palm includes rubber and cocoa.

In this research, an adapted Hartman model is used to compare the sales performance and carbon revenue performance between oil palm, rubber and cocoa smallholder farmers. Within 30 years timeframe, rubber have better net present value in terms of sales revenue and carbon revenue compared to oil palm. Cocoa, on the other hand, performs financially worse than rubber and oil palm in both sales and carbon revenue.

However, carbon credit project also has high initial cost of registration and preparation. For farmers that has area of 1 hectare or lower, it is recommended to to start the carbon credit project jointly with other farmers in the same area. Furthermore, the farmers must also consider the price fluctuation of the carbon credit and also the demand of the alternative commodity before they should decide to shift their commodity.

Contents

Chapter 1 Introduction

1.1 Background

The Paris Agreement on Climate Change proposed to limit the global temperature increase below 2 °C compared to the pre-industrial temperature level (Spaargaren & Van Koppen, 2019). The agreement identified greenhouse gas (GHG) emissions, especially carbon emissions as one of the causes of climate change (Spaargaren & Van Koppen, 2019). The agreement also encouraged participating countries to voluntarily submit a set of plans and measures called Nationally Determined Contribution (NDC) in achieving the objectives of limiting the global temperature increase (Spaargaren & Van Koppen, 2019). Assuming the portion of the world's renewable energy rises by 2% per year, the world's government would need to cut emissions by at the latest 2035 to attain the target from the Paris Agreement (Aengenheyster et al., 2018).

In their NDC, the Indonesian government committed to reduce the national GHG emissions by 29% in 2030 (Republic of Indonesia, 2016). Related to this commitment, one of the government's strategies is the plan for a pilot nationwide carbon market in 2020 (Munthe & Nangoy, 2020). Carbon trading has been shown to be effective in reducing emissions while also generating additional revenues in several regions, such as in the European Union, Switzerland, California, Quebec and some states in the United States of America (Narassimhan et al., 2018).

The Indonesian Government is collaborating with the Partnership for Market Readiness (PMR) from the World Bank to assess and to design a carbon market suitable for the country (The PMR, 2019). The project identified several national sectors with high carbon emissions, such as power, cement, pulp and paper, chemical, fertilizer, food and beverage, iron and steel, textile, and ceramic and glass sector. Based on the latest report, the government plans to implement a combination of voluntary emission trading system (ETS), crediting mechanism, and setting up carbon cap for the identified sectors (The PMR Indonesia, 2019).

For forestry industry in general, the plan for the national emission crediting mechanism could potentially add a new incentive for GHG reduction effort. One mechanism to gain compensation for emission reduction effort in the forestry sector is the REDD+ mechanism (Boucher, 2015). REDD+ stands for reducing emissions from deforestation and forest degradation (REDD) with the addition (+) of the conservation role, sustainable management of forests and enhancement of forest carbon stocks. In REDD+ program, an incentive is developed by policymakers to give compensation for emission reduction effort related to deforestation and forest degradation mitigation (G. Liu et al., 2020), with funding coming from the government, Non-Government Organisation, research institutes and private companies (Dixon & Challies, 2015). The most recent examples of REDD+ implementation in Indonesia was the first payment from the Norwegian government to the Indonesian government in 2020 amounting US$56.15 million as part of the pledge from both countries in 2010 to reduce deforestation and carbon emission (Irama, 2020; Pinandita, 2020). However, the application of REDD+ would also mean a trade-off between utilising the land for REDD+ or planting commodities. The gap between the profits from selling the commodities and the REDD+ payment will determine whether a plantation owner decides to join the program or not (G. Liu et al., 2020).

Oil palm plantation is one of the most popular forestry industries in Indonesia (Corley & Tinker, 2015). With further processing, oil palm can produce palm oil with various qualities. Together with Malaysia, Indonesia contributed to around 85% of the world's palm oil production (Sumarga & Hein, 2016). As palm oil is the most profitable land use choice in Indonesia (Feintrenie et al., 2010), REDD+ could only financially outperform oil palm in some conditions, such as in regions with low oil palm-suitability or in areas with high oil palm-suitability, but with high carbon price and high carbon stock (Abram et al., 2016). However, in majority of the cases converting the land to oil palm plantation is still more economically profitable due to the limited availability of carbon credits from REDD+ (Butler et al., 2009). Furthermore, in Indonesia the scheme is poorly understood by the community and local government, in addition to low socialisation effort from the government and uncertainty of carbon credit buyers (Djaenudin et al., 2016).

Another alternative to gain compensation for oil palm plantation is through the voluntary carbon market, which is defined as the carbon market operating outside of the mandatory government regulation that limits the emissions of GHG (Woodside, 2016). Compared to the cap-and-trade market by the government, social corporate responsibility has been cited as the primary drivers for the market, with buyers coming from industries that has not been regulated by climate policies (Hamrick & Goldstein, 2015). Several standards organisations, offset registries and verification procedures such as the Verified Carbon Standard (Verra), The Gold Standard and Plan Vivo have also existed to provide credibility of the carbon offsetting project for the buyer (Donofrio et al., 2020; Woodside, 2016). Based on the latest report, the volume of global carbon offset transaction in the forestry sector of the voluntary carbon market in 2019 reached up to 36 ton of Carbon Dioxide (CO_2) equivalent with an average price of US$ 4.3 per ton CO_2 equivalent (Donofrio et al., 2020).

The voluntary carbon market is considered as more flexible than the mandatory market because of to less complex bureaucracy, lower transaction costs and faster project development, which enables small scale project to enter the market (Benessaiah, 2012). Projects that can clearly communicate value beyond emissions reductions such as poverty alleviation, the involvement of local community and biodiversity could appeal to more buyer and high price per credit, which is why smallholder land owner could benefit from the market (Woodside, 2016; Hamrick & Allie, 2015). There are several examples of smallholder plantation owner participating in the voluntary carbon market, such as the community tree planting program in Uganda (Cooleffect, 2020), the planting food forest program in the Netherlands (Trees for All, 2020), the Agroforestry climate compensation project in Kenya (Vi Agroforestry, 2020), and the healthy soil farmers project in the United States (Nori, 2020).

The emergence of the carbon market in Indonesia provides the opportunity for smallholder plantation owners to gain additional profit from carbon sequestration effort. Commodities with higher carbon sequestration potential might financially perform better than the more popular commodities such as oil palm, depending on the compensation system, market availability and carbon price. This research will focus on exploring the voluntary carbon market potential for smallholder farmers as an alternative to oil palm commodity.

1.2 Research Objective

The study aims to explore the opportunity of alternative commodities options for smallholder oil palm farmers by investigating the financial potential of other commodities with high carbon sequestration in consideration to the voluntary carbon market potential in Indonesia.

1.3 Research Questions

The general research question to achieve the objective of the research is:

Which commodity could financially outperform oil palm in smallholder farmers in Indonesia with consideration to voluntary carbon market potential?

This research will focus on the financial performance of alternatives commodities since it is a common indicator that can be used directly for decision-making process of the farmers. To address the voluntary carbon market potential, the question will be answered by combining the revenue gained from selling the commodities and the potential carbon revenue gained from carbon credit compensation. Additionally, this research will also explore two sub-research questions to support the main research question as follow:

1. Which voluntary carbon credit methodology can be used to gain carbon compensation for smallholder oil palm farmers in Indonesia?

The first sub-research question will be focused on exploratory analysis of the available voluntary carbon market options that can be implemented for smallholder farmers in Indonesia. The result from the analysis will be used to determine the feasibility of the available carbon market and will further be applied in the carbon revenue model for the main research question.

2. What are the potential commodities options suitable in Indonesia which have a higher carbon sequestration than oil palm plantation?

The second sub-research question will explore the available commodities that have a higher carbon sequestration compared to oil palm. A higher carbon sequestration commodity is expected to give more carbon revenue to the farmers.

The result from both sub-research questions will be used as an input for the model to answer the main research question. Specifically, the first sub-research question will define the carbon revenue function used in the model, while the second sub-research question will determine the alternative commodities that is being compared to the oil palm.

1.4 Methods

In accordance with the research objective, this research has also established one main research question and two sub-research question. This research will combine a literatures review and a financial modelling to answer the research questions. To answer the research questions, two main methods is used in this research.

The first sub-research question will be answered by performing a literature review of the existing voluntary carbon market suitable for smallholder plantation owner that can be applied in Indonesia. The second sub-research question will be addressed by referencing past research to compare the carbon sequestration potential of different commodities commonly planted in Indonesia. The main research question will then be answered by comparing the net present value of different commodity options using adapted Hartman (1976) optimal forest resources model which values both the harvest revenue and the environmental values (in this case, the carbon sequestration). In the model, the environmental value of the forest/plantation is added in addition to the monetary value of the tree. A summary of the research questions and methods can be seen in Table 1.1. Further explanation on the Hartman optimal forest resources model will be elaborated in Chapter 6.

	Research Question	**Methods**
Main Research Question	Which commodity could financially outperform oil palm in smallholder farmers in Indonesia with consideration to voluntary carbon market potential?	Hartman Optimal Forest Resources Model
- **Sub-Research Question 1**	Which voluntary carbon credit methodology can be used to gain carbon compensation for smallholder oil palm farmers in Indonesia?	Literature Review
- **Sub-Research Question 2**	What are the potential commodities options suitable in Indonesia which have a higher carbon sequestration than oil palm plantation?	Literature Review

Table 1.1. Summary of research questions and methods of the research

1.5 Research Outline

The theoretical framework about the voluntary carbon market and carbon price is elaborated in Chapter 2. Chapter 3 provides the details of the smallholder oil palm plantation case in Indonesia. In Chapter 4, exploration about the available voluntary carbon market options for smallholder plantation owners in Indonesia is explored. Chapter 5 explores different high carbon sequestration commodities options compared to oil palm. The research methods and model are corroborated in Chapter 6 and the data collection methods are explained in Chapter 7. In Chapter 8, the financial performances of the alternative commodities are put into the model to be compared with oil palm plantation's performance. At the end of the report, Chapter 8 discusses the result of the research and Chapter 9 concludes with the conclusion of the research.

Chapter 2 Carbon Market: Theory and Framework

2.1 Carbon Market Theory and Definition

2.1.1 Carbon Emission

Carbon is an element with essential functions for living organisms, from being used as the component of many organic molecules, to becoming a part of a chain process to provide metabolic energy (Cunningham & Cunningham, 2017). Given its importance to virtually all living things, carbon is involved in almost every activity on earth. The natural carbon cycle mainly includes carbon release activities (e.g., respiration, decomposition of corpses, and volcano eruption) and carbon capture activities (e.g., photosynthesis and some geographical rock formation) (Cunningham & Cunningham, 2017). One of the carbon forms in nature is CO_2, which is an important part of the respiration and photosynthesis process.

Human activities have disturbed the carbon cycle balance by increasingly emitting additional CO_2 from polluting activities such as the combustion of fossil fuels (Wilcox, 2012). This process releases the carbon stored in materials originating from the remains of organic matter, for example coal, natural gas, petroleum, and other forms of fossil fuels. Due to the substantial growth of the carbon release activities, the natural carbon capture activities could not keep up with the surge which leads to an increase of the CO_2 concentration in the atmosphere by 31% compared to preindustrial period (Cunningham & Cunningham, 2017). It is estimated that 30 gigatons of CO_2 were generated each year only from human caused sources, as seen in figure 2.1 (Ritchie & Roser, 2017; Wilcox, 2012).

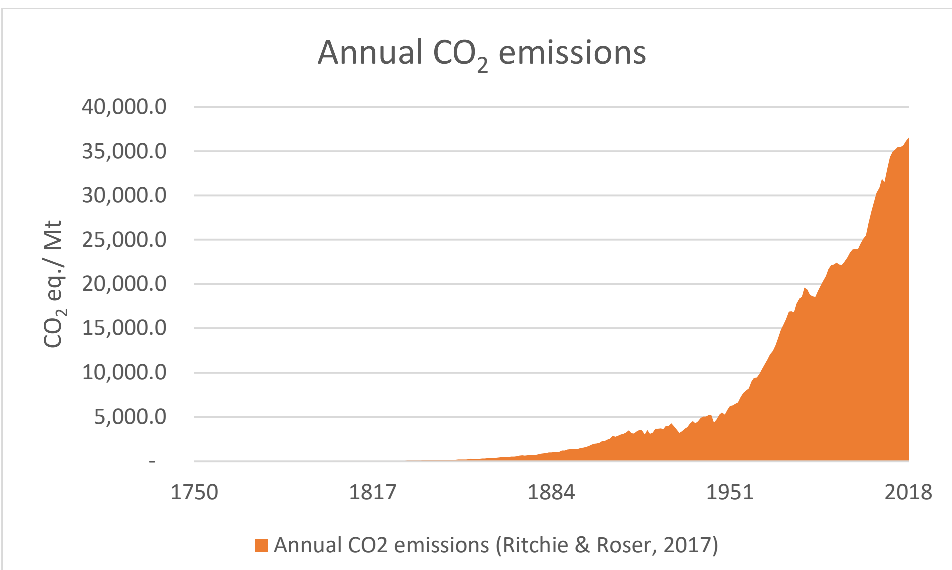

Figure 2.1 Annual CO_2 Emissions (Ritchie & Roser, 2017)

As CO_2 has heat trapping property (the greenhouse effect), the increase of CO_2 concentration in the atmosphere will have permanent climate impacts, including global warming, extreme weather anomaly and the rise of sea level (Solomon et al., 2009). These climate impacts were estimated to last for hundreds of years even if humanity could stop producing the emission immediately (Ramanathan & Feng, 2008). Furthermore, the change in the global climate condition would also affect the ecosystem around the world, such as the warmer condition in the polar region which was observed to impact the decline of local flora and fauna population due to unsuitable living conditions (Cunningham & Cunningham, 2017). A report made by CE Delft in the Netherlands put the environmental shadow price impact of climate change from CO_2 emission and its equivalent to approximately at €57 per ton (de Bruyn et al., 2018). The price represents the monetary value of the loss of economic and social well-being caused by an additional emission of the pollutant to the environment.

2.1.2 Market Failure and Property Rights of the Carbon Emission

Due to the widespread use of fossil fuel technology, most human activities would release carbon emission, both directly and indirectly. Unfortunately, these activities did not take into account the cost of carbon emission to such as climate change and air pollution. This unintended effect of the activities is called as externality (Cornes & Sandler, 1996).

Perman et al. (2011) mentioned that externality occurs when production or consumption activities of one entity unintentionally affect the utility or profit of another entity, and no compensation is made by the originator to the involved entity. They described externalities as one of causes for market failure, which is a condition where the actual market situation departs from the ideal condition. This further causes inefficiency of welfare distribution and a net loss in the economic values of the activities. They further explained that with the lack of compensation by the originator, the entity would not consider the unintended effect of the activities. If the impact is beneficial, then there will not be enough of it to achieve ideal welfare allocation, while if the impact is harmful there will be too much of it which causes more economic loss than it should.

In 1960, Ronald Coase addressed the issue of negative externalities (for example, the smoke from a factory) by proposing to treat the emission as property rights which could be transferred using market mechanism. Segerson et al. (1986) defined property rights as a combination of characteristics that shows how the owner is entitled to the related resources. They further explained that the characteristics include the ability to divide or transfer the right, degree of exclusiveness of the right, duration and enforceability of the right, and the authority to obtain returns from the right. Treating emissions as property rights is a way to internalize, or recognise externalities (de Godoy & Saes, 2015).

Coase (1960) argued that the common business model only considers factors of production which affected the entity physically, such as the land or factory building, while disregarding further action that could arise from those factors, such as the creation of smoke or noise. He further elaborated that just as having ownership over the land would prohibit other people from building their house there, the existence of smoke from the factory would also prevent them from having unpolluted air. Coase concluded that by giving ownership to these other factors, then the consequence of using the factor of production could then be accounted for.

However, assigning ownership of those other factors is not easy to do, especially when the case involves many parties (Perman et al., 2011). This kind of situation would lead to bargaining between the parties involved to reach out the best outcome for everyone. De Godoy & Saes (2015) defined this bargaining cost as transaction cost, which is the resource allocated to achieve the production of goods. They further explained that in the case of emission, transaction cost would involve things such as project validation, the assessment of the emission quantity, monitoring process, certification, administration cost, and issuance of emission reduction certificates.

2.1.3 Carbon Market as Economic Policy Instrument

The Coase theorem has become the core for many emission mitigation policies, especially the market-based instrument (de Godoy & Saes, 2015). Market-based instrument aims to change the behaviour of entities involved by altering their costs or benefits and creating incentive for them (Perman et al., 2011). One of the most common pollution that is regulated through the market-based instrument is carbon (CO_2 and CO_2 equivalent), which is popularly called as carbon market or carbon trading.

An example of carbon market mechanism is the cap-and-trade scheme, where the government (or other authoritative figure) puts a limit of the pollution that can be emitted by the stakeholders involved and allow trading of the emission permits between them (Perman et al., 2011). In the cap-and-trade scheme, the government first needs to set the total emission limits that can be emitted by the regulated firms or industry. Based on the total limits, the government could sell the permits by auction or allocate it to the potential polluter. Afterwards, a system will be established to monitor the pollution emitted by the related entity, while a penalty will be imposed to entity which emits pollution above the allocated permit. The entities involved in the system can freely trade the permit with each other to avoid exceeding their own limit or if they have a surplus of the permit.

In the cap-and-trade scheme, some entity will hold more permits than the quantity of their own actual emissions, while other entities will not have enough permits to cover their own emission. With the trading mechanism, the entity that lacks sufficient permit will have the incentive to purchase for additional permit. This decision to purchase is determined based on price of the permits compared to the cost of reducing one more unit of their pollution, which is also known as the marginal abatement cost. Each entity will value the tradable permits differently depending on their marginal abatement cost. The entity with a higher marginal abatement cost will have an incentive to purchase additional permits at a price less than their cost, while the entity with a lower marginal abatement cost is hoping to sell some of their permits at a price higher than their cost. Based on this mechanism, a market will be established for permits and a single equilibrium market price will emerge (Perman et al., 2011).

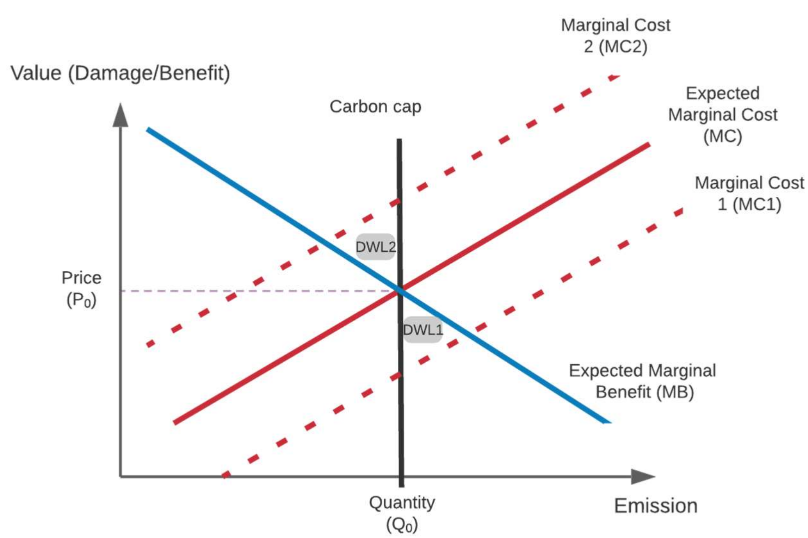

Figure 2.2 Cap-and-Trade Deadweight Loss

Suppose a carbon-emitting product has an expected marginal benefit of MB and an expected marginal cost of MC (Figure 2.2.). In this case, the ideal carbon cap will be set at the equilibrium quantity of $Q_{0,}$ where the marginal cost of emission equals to the marginal benefit of emission. If the actual marginal cost is lower than expected (MC1), then the carbon cap will produce deadweight loss of DWL1. The deadweight loss comes from the opportunity loss to gain more benefit from producing more emissions. On the other hand, if the actual marginal cost is higher than expected (MC2), then the carbon cap will produce deadweight loss of DWL2. In this case, the deadweight loss comes from the excess of cost from producing more emissions than it should.

Another variation of the carbon market mechanism is the carbon offsetting scheme (Perman et al., 2011). In this scheme, the entity participating in the scheme is allowed to reduce the total calculation of their carbon emission by contributing to designated carbon reduction project as specified by the ruling environmental agency. For example, suppose an entity emits 10,000 tonnes of CO_2 equivalent per year with a permit of only 8,000 tonnes of CO_2 equivalent per year. To achieve the permit limit, the entity must abate their own pollution by 2,000 tonnes of CO_2 equivalent or purchase additional permit. In the offsetting scheme, the entity will have another option to engage in a project which has equivalent carbon reduction amount. In this case, the entity's decision will be based on their marginal abatement cost against the marginal cost of the offsetting project. However, projects that can be engaged are limited based on government regulation. For example, some carbon markets would allow cross-country carbon offsetting project, while others would limit the project depending on the entity's regional location.

The other popular market-based instrument is the carbon tax, where an entity emitting above the regulated carbon would have to pay economic compensation to the government/regulator amounting to the social cost of the emission (Perman et al., 2011, Pindyck, 2017). The money gained from the tax could be used for projects related to the emission which aim to reduce the damage caused (levy) or to produce tax income for the government/regulator. Carbon tax puts the government in an active role of identifying the emission cost at industry level to determine the tax price, including collecting and monitoring the tax, while also being politically harder to implement (Perman et al., 2011).

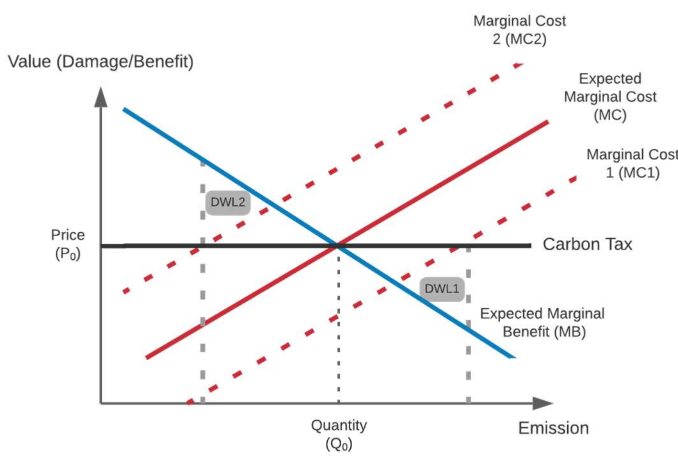

Figure 2.3 Carbon Tax Deadweight Loss

Suppose a carbon-emitting product has an expected marginal benefit of MB and an expected marginal cost of MC (Figure 2.3.). In this case, the ideal carbon tax will be set at the equilibrium quantity of P_0 where the marginal cost of emission equals to the marginal benefit of emission. If the actual marginal cost is lower than expected (MC1), then the carbon tax is higher than it should and will produce deadweight loss of DWL1. On the other hand, if the actual marginal cost us higher than expected (MC2), then the carbon tax is lower than it should and will produce deadweight loss of DWL2. Lower carbon tax means that there will be excess of emissions produced from the expected condition.

The implementation of the carbon market and carbon tax are not exclusive to each other. Several European countries implement a hybrid form of tradeable permit and tax for different emissions (World Bank, 2020). Consistent with the objective of the research, this thesis will focus more on the carbon market implementation.

2.2 Forms of Carbon Market Around the World

The Kyoto Protocol in 1997 is one of the starting points where different emission reduction policies started to become widely considered to be implemented globally (Spaargaren & Van Koppen, 2019). The treaty introduced an international carbon trading market which can be participated by the ratified members. Outside of the Kyoto protocol mechanism, other forms of carbon markets which aim to manage the carbon emission also emerged in different regions. The World Bank (2020)) reported that almost half of the emissions are priced at less than US$10/ ton CO_2 equivalent (Around €8), which is only around 14% of the estimated climate change damage of the substance (€57/ ton CO_2 equivalent based on the environmental price handbook by de Bruyn et al., 2018). This sub-chapter will introduce existing carbon markets mechanisms throughout the world.

2.2.1 Kyoto Protocol Carbon Market

There are three market-based mechanisms that were introduced by Kyoto Protocol to meet the emission reduction target as follows.

a. Emission Trading
   In Emission Trading (ET) scheme, countries that are subject to limit their greenhouse emissions (Annex B parties) are given Assigned Amount Units (AAU), which is their caps on allowed emissions. If the country has spare AAU, then they can trade the excess with other countries that need them (UNFCCC, 2010). During the first commitment period of Kyoto protocol commitment (2018-2012) the trading in ET had not been optimal (Kossoy & Ambrosi, 2010) due to the high target set in the Kyoto Protocol. Grubb et al. (2010) observed that the emissions from several countries, such as former Soviet Union and East European countries were below the target sets, due to overestimation of economic developments and not because of their climate change policies.

b. The Clean Development Mechanism
   In the Clean Development Mechanism (CDM), Annex B countries are encouraged to implement projects related with emission reduction in developing countries. Countries involved will be given certified emission reduction (CER), which is a form of carbon credit which can be used to meet Kyoto target (UNFCCC, 2010). CDM showed significant success based on the emission reduction compared to the other mechanism (Grubb et al., 2010).

c. Joint Implementation

The Joint Implementation (JI) mechanism is similar to the CDM. Instead of performing projects with developing countries, in JI the Annex B country accomplishes projects with another Annex B country and earns emission reduction units (ERU) as credit (UNFCCC, 2010). JI projects are aimed especially at industrial countries.

The protocol defined these mechanisms as flexibility mechanisms, which gives Annex B countries alternatives means to achieve their target of emission reduction. The protocol target was renewed under the second commitment, under Doha Amendment to the Kyoto Protocol with a period from 2012-2020 (de Godoy & Saes, 2015).

2.2.2 Mandatory Carbon Market

Mandatory or compliance carbon market refers to the regulated carbon market scheme in several regions/countries which requires specific industries/firms to participate in the market (Bayon et al., 2013). In the mandatory carbon market, the responsibility of the government is important to regulate the market. This role includes, but not limited to, the distribution/arrangement of the emission permit, enforcement of non-compliance, and monitoring the trading process. In the following section, several mandatory carbon markets are briefly described.

a. European Union Emissions Trading Scheme

European Union (EU) Emission Trading Scheme (ETS) began to operate in 2005 and consist of several phases, which is the trial trading period (2005 to 2007), the Kyoto Protocol period (2018-2012), the third period from 2013 to 2020 which coincide with the second Kyoto Protocol commitment period, and the planned phase 4 which will cover the period of 2021 to 2030 (de Godoy & Saes, 2015; The European Union, 2020). EU-based companies in selected sectors are obliged to participate in the scheme. The EU ETS targeted at least 40% reduction in GHG emission from 1990 levels by 2030.

In phase three of the EU ETS, a single cap is applied throughout the whole EU member and permits are distributed through auction rather than free allocation (The European Union, 2020). The cap is going to be reduced over time to achieve a reduction of overall emission. International carbon credit offsetting system also existed in the scheme. However, the usage of international offsetting has been severely limited in phase three. Currently, the EU ETS still holds the largest share of global emissions covered by carbon pricing initiatives around the world with the latest carbon price of €32/ ton CO_2 equivalent at the end of 2020 (Ember-Climate, 2021; World Bank, 2020).

b. New Zealand Emissions Trading Scheme

The New Zealand Emissions Trading Scheme (NZ ETS) has been active since 2010 and was the first cap-and-market outside of the EU ETS (de Godoy & Saes, 2015). Leining et al. (2020) described that the trading scheme involves major Greenhouse Gasses sources such as the forestry, stationary energy, industrial process, transport sectors, synthetic gas, waste industry and biogenic emissions from agriculture. Compared to other big emission trading markets, the NZ ETS only has a link to the Kyoto Protocol mechanism credit. The research concluded that NZ ETS has not successfully reduced domestic emission by a significant amount due to low emission prices and policy uncertainty. The latest carbon price in 2020 is reported to close at NZ$37.55/ ton CO_2 equivalent (€22.15/ ton CO_2 equivalent) (carbonnews.co.nz, 2021).

c. China National Carbon Trading Scheme

Parenteau & Cao (2016) explained in their report that China started the testing of National Carbon Trading Scheme by having pilot carbon market in seven zone that were the largest emitters of greenhouse gasses due to production of cement, heat, electricity and fossil fuel extraction and participants from firms with emission of more than 10,000 tons of carbon annually. They further elaborated that there were two kinds of permit in the carbon market, which is new entry allowance that are freely distributed and governmental allowance which must be sold or auctioned. Each zone must perform monitoring, reporting and verification for the greenhouse gas emissions where failure to do it will result in the reduction of new entry allowance, publication of the firm's compliance status and restricting access to special funds while excess emission will result in monetary penalty with 3 times the allowance price. Parentau and Cao identified that transparency, price volatility and integration of the scheme with other environmental policies were the major issues during the pilot project implementation. Although still in pilot and development, the world bank estimates that the China National Carbon Trading Scheme will cover a large carbon market share in the future (World Bank, 2020).

2.2.3 REDD+

Reducing Emissions from Deforestation and Degradation (REDD) is a form of carbon mitigation scheme that is introduced by the United Nations Framework Convention on Climate Change (Bhullar, 2013). At the 2007 United Nations Climate Change Conference, the scheme further improved into REDD Plus (REDD+) with the addition of conservation and enhancement of forest carbon stocks, and sustainable management of forest. REDD+ implementation is similar to CDM in several ways. Bhullar (2013) distinguished both projects by describing that REDD+ is centred in tropical developing countries, focusing on forestry with national or sub-national scale and higher involvement from host countries. This is in contrast with CDM, that are mostly project-based in countries with emerging economies and involves less host country involvement. However, both projects produced CER as carbon credits which can be sold to Annex B countries as part of their emission reduction target commitment. The carbon credit produced from the project is calculated by the emission level after REDD+, subtracted with the emission level before REDD+ (baseline) (Djaenudin et al., 2016).

In the result-based payment REDD+ scheme, the forest manager of a determined forest will be compensated based on the addition of carbon stored in each period (Indrajaya et al., 2016). The carbon baseline will be set at the beginning of the scheme, while measurement, reporting and verification (MRV) procedure is performed periodically to determine the addition of stored carbon. Based on the MRV calculation, the result will be converted into applicable carbon credit and the forest owner is compensated accordingly. To increase the carbon storage, several methods can be performed by the forest manager, such as the use of reduced impact logging techniques (Indrajaya et al., 2016) and managing the deforestation and forest degradation level (Djaenudin et al., 2016).

In recent years, REDD+ has been excluded as possible carbon offsetting credit in several international carbon markets such as the EU ETS (The European Union, 2020). Furthermore, the opportunity cost from REDD+ implementation compared to commercial usage of the land use is financially unsound (G. Liu et al., 2020). Due to these reasons, countries or forest owner that want to implement REDD must also be prepared to have additional financial support, especially due to the high initial cost of MRV implementation (Köhl et al., 2020). Additionally, from the investor's perspective, there might be cheaper options than REDD+ to offset their carbon footprint (Laing et al., 2016). However, Laing et al. (2016) also noted that the additional benefits of biodiversity protection and community development are considered to be very appealing for corporate social responsibility objective.

2.2.4 Voluntary Carbon Market

Outside of the compliance market, more than US $5 billion (around €4.1 billion) has been voluntarily spent by government, companies and individuals for projects related to GHG reduction and removal over the past 20 years (Donofrio et al., 2020). This market for carbon offsetting project is known as voluntary carbon market and consist of actors which produce carbon credits (project owners) and buyers who purchase them (Woodside, 2016). Other stakeholders involved in the voluntary markets include brokers who market the carbon project to the buyers, organizations that develop the standards and methodologies used, the verification firms and the organization that register the carbon project. Although there is no centralised standard, several organisations have emerged to provide guidance and protocols for the development, verification, monitoring, and reporting of carbon credit projects. Some of the widely used standards are from carbon standard organisation such as Verra, The Gold Standards, Plan Vivo Foundation and the Climate Action Reserve.

Different from the compliance market, the carbon price in the voluntary market is highly dependent on the standard used, type of project and value created (Woodside, 2016). In 2019, the biggest transaction in voluntary carbon market occurred in the renewable energy sector which has 42.4 Ton CO_2 equivalent volume transaction with the forestry and land use following with 36.7 Ton CO_2 equivalent (Donofrio et al., 2020). However, the renewable energy sector only has the average price of US$1.4/ Ton CO_2 equivalent (€1.15/ ton CO_2 equivalent) compared to the forestry and land use with the average price of US$4.3/ Ton CO_2 equivalent (€3.53/ ton CO_2 equivalent). This means that in terms of value involved, the forestry and land use sector contributed a higher value at US$159.1 million compared to US$60.1 million in renewable energy sector.

Voluntary carbon market remains popular among buyers due to several reasons. First, some stakeholders perceived voluntary market as a better alternative compared to UN's CDM market since the standards also consider the social and economic factors in addition to the carbon storage function (Woodside, 2016). Co-benefit from the project was found as an important factor to strengthen their market competitiveness, especially in forest carbon credit project (Lee et al., 2018). This is important since the non-mandatory nature of the market means that the actors involved must create value to attract demand from potential buyers. Additionally, the voluntary carbon market is also considered as more flexible in accommodating the demand of the credit buyers compared to CDM or REDD+. This is highlighted with less bureaucracy, lower transaction costs and faster project development (Benessaiah, 2012), which is why it is attractive to a wider range of stakeholders. This advantage also makes small scale project owner easier to participate in the market.

Although it offers flexibility to the user, the multiple standards also caused difficulties in determining which one is the best to use, especially among small-scale producers (Merger & Pistorius, 2011). This is one of the reasons why, in their early development, the voluntary carbon market was criticized with the lack of transparency and the poor quality of the carbon offsets. Another concern with the voluntary carbon market is how the market demand is highly affected by the development of policy related to climate change and public perception about environmental issue (Hamrick & Goldstein, 2015). The uncertainty of these factors is what makes it difficult for the producer to estimate carbon offsetting demand in the future.

2.3 Carbon Market Situation in Indonesia

2.3.1 Indonesia Carbon Reduction Commitment Progress

In 2016, Indonesia submitted their NDC as part of commitment to the Paris agreement (Republic of Indonesia, 2016). In the document, Indonesia targeted to reduce emissions by 26% by itself and 41% with international support by 2020. The pledge was legitimated nationally through Presidential Decree No. 61/2011 about Greenhouse Gases Emissions and Presidential Decree No. 71/2011 about Greenhouse Gases Inventory. The document further explained that REDD+ will be a significant component to achieve this target. Based on the United Nations report in 2019, the assessment of forest reference emission level of Indonesia showed an increase from 568 million-ton CO_2 equivalent in 2013 to 593 million-ton CO_2 equivalent in 2020, mainly due to emissions from peat decomposition.

In Indonesia, REDD+ is implemented by also involving the local communities. However, the carbon credit scheme was poorly understood by the community and local government, in addition to low socialisation effort from the government and uncertainty of carbon credit buyers (Djaenudin et al., 2016). The most recent examples of REDD+ successful implementation in the country was the first payment from Norwegian government to Indonesian government in 2020 amounting $56.15 million as part of the pledge from both countries in 2010 to reduce deforestation and carbon emission (Irama, 2020; Pinandita, 2020); Irama, 2020).

2.3.2 Carbon Market Plan and Potential in Indonesia

The National Carbon Scheme (*Skema Karbon Nusantara*) was a prototype plan for carbon trading project based on the cap-and-trade mechanism prepared by the National Council of Climate Change of Indonesia (*Dewan Nasional Perubahan Iklim*) under Susilo Bambang Yudhoyono's presidential cabinet (Irama, 2020). In the plan, the carbon credit would have been recorded and tracked by the Ministry of Environment with an estimated date of implementation in 2014. The scheme would be focused on renewable energy, waste processing, agriculture, and forestry as potential carbon credit producers. The plan was presented internationally in COP19 in Warsaw, on the Joint Crediting Mechanism session between Indonesia and Japan (Japan Ministry of Environment, 2013; National Council of Climate Change, 2013). In 2015, the National Council of Climate Change of Indonesia was merged into the Ministry of Environment and Forestry by the presidential decree of the new president, Joko Widodo (Irama, 2020). As of the date of the merger, the national carbon scheme has not been implemented.

Under his term, Joko Widodo issued several presidential decree that served as the basis for carbon trading, which are Presidential Decree 46/2017 about Environment Economics Instrument, Presidential Decree 77/2018 about Environment Fund Management and the establishment of Environmental Fund Management Agency based on Decree of Finance Minister KMK 779/2019 (Irama, 2020). In her analysis, Irama described that the Agency can serve as the basis for Indonesian involvement in global carbon trading with the function of managing revenue received from carbon trading activity in addition to the fund for environmental protection and conservation activities. The research estimated that potential non-tax revenues ranging from Rp51 billion up to Rp180 billion (€ 2.9 million - €10.2 million) could be generated by sales of carbon credit in the global carbon market. The pilot carbon market project is estimated to start in 2020 (Munthe & Nangoy, 2020). On the other hand, Dissanayake et al. (2020) concluded that joining a shared jurisdiction of regional emission trading is more realistic to be implemented by Indonesia in the short term compared to developing the domestic carbon market.

In addition to the government's effort to set up a carbon market environment, carbon emissions disclosure is also not a new thing for Indonesian companies. Currently, Indonesia has a voluntary disclosure policy for carbon emissions in publicly traded companies. Nurdiawansyah et al. (2018) published that in manufacturing industries, company size, profitability and media exposure have positive effects on the carbon emissions disclosure willingness. However, the writer also noted that the policy does not specify the standards of carbon emission information that must be disclosed, which causes a difference in quality of information in the company observed.

Indonesia has started the plan to implement a carbon reduction policy since 2013 with the help of the PMR, a multi-donor trust fund founded by the World Bank (The PMR, 2019). The organisation collaborates with the Coordinating Ministry of Economic Affairs of Indonesia to assess and prepare for implementation of market-based instruments for climate-change mitigation, including cap-and-trade for greenhouse gasses emission and carbon pricing. For this project, Indonesia was allocated with a grant of USD 3 million, which will be executed by the PMR, Indonesian government and supported by the United Nations Development Programme (UNDP). The extent of the project includes exploring different market instruments, building the domestic infrastructure for the carbon market, and establishing MRV framework, especially in the power sector and cement industry.

According to their latest report for the Indonesian project (The PMR Indonesia, 2019), several components of the project has been completed, which are the profiling emissions in the power and industry, the design of governance aspects of an MRV system, a pilot MRV system and the organization, communication, consultation and engagement, with ongoing phase of the development of a market-based instrument framework. The project identified sectors which have high GHG emissions mainly in the **power sector** and 8 energy-intensive sectors which are **cement, pulp and paper, chemical, fertilizer, food and beverage, iron and steel, textile, and ceramic and glass**. In the profiling component, the project developed GHG emissions baseline for the chosen sectors and estimated the potential of emission reductions and abatement cost of mitigation actions.

The PMR report concluded that ETS is suitable for Indonesia, especially for energy-intensive sectors such as power plants, cement and fertilizer which already have complete data related to historical emission and baseline calculation. A combination of voluntary ETS, crediting mechanism called as Indonesia Certified Emission Reduction (ICER), and cap level is currently being assessed for pilot implementation in the power, cement and fertilizer sector. Currently, the Indonesian government has established a National Registration System (Sistem Registri Nasional) for climate change as the initial step to account for all climate change mitigation efforts in the country. The government also planned to integrate the crediting mechanism monitoring into this system.

In addition to the planned mandatory carbon market, several forms of voluntary carbon markets have also existed in Indonesia. One of the biggest privately owned REDD+ project in Indonesia is the Rimba Raya Project (Rimba Raya, 2014), which is validated and registered under Verra. It protects almost 65,000 hectares of peat forest area in Central Kalimantan, Indonesia. Due to the sheer size of the project, the carbon offset credit is offered in several international carbon marketplace associated with Verra, both for personal and corporation carbon offsetting purpose. The project is proven to demonstrate effective carbon sequestration, biodiversity preservation and community engagement while also getting sufficient funding from the voluntary carbon market through international carbon credits (Enrici & Hubacek, 2018). Given the status of the area after being designated as REDD+ project, it also prevented legal palm oil expansion and logging to encroach to the area. Other REDD+ project has also known to operate in Indonesia, such as the Kapuas Hulu project and Harapan Rainforest project. However, it is harder to evaluate the successfulness of these projects due to the lack of independent monitoring to determine how carbon and biodiversity levels have improved since the project started (Enrici & Hubacek, 2018).

A smaller example of carbon marketplace in Indonesia is Jejak.in, which is a tech start-up which offers tree adoption in conservation project for organisation or personal carbon offsetting (Jejak.in, 2020). Though still growing in popularity for national buyers, the biodiversity and large natural area in Indonesia provides opportunities for carbon offsetting project to grow and appeal international customers.

Chapter 3 Case Study of Indonesia Smallholder Oil Palm Plantation

3.1 The Oil Palm

Oil palm is regarded as the most efficient vegetable oil producer compared to other oil crop (Corley & Tinker, 2015). It is mostly found in the areas of equatorial tropics such as Africa, Southeast Asia and South America, with Indonesia and Malaysia as the major producer. Even though oil palm has six to seven times labour demand compared to other crops, it produced the highest yield per hectare of up to ten times of more oil (Davidson, 1993).

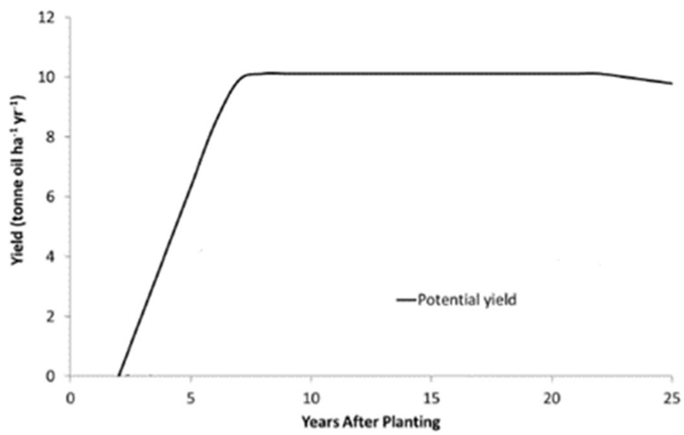

Figure 3.1 Oil Palm Yield Estimation and Lifecycle (Woittiez, 2019)

Woittiez (2019) summarised that there are several phases in oil palm cultivation. In the pre-planting years, oil palm seeds are grown and nurtured in polybags for around 6-12 months. After the seeds are ready, they are planted in the field and begin the immature phase, where the oil palm is not yet harvestable for around 2 to 3 years after planting. The next phase is called as young mature phase where the yield grows linearly for around 3 to 4 years. In the mature phase, the yield will reach their optimum level with a stable curve over the years for around 6 to 7 years. Finally, in the last phase, the yield will start to decline until it is not economically profitable to continue harvesting. At around 20 years to 25 years after planting, the farmers will start the field preparation for the next replanting cycle of the oil palm where the whole cycle will begin again in the same field. A chart of oil palm life cycle can be seen in figure 3.1.

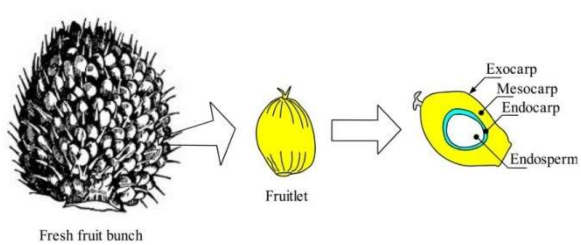

Figure 3.2 Oil Palm Fruit Structure (Harun et al., 2013)

The main product from oil palm is the Crude Palm Oil (CPO), which are gained from mechanically processing the Fresh Fruit Bunch (FFB) of oil palm. In addition to the flesh of the fruit (mesocarp), the central part (kernel which consist of endocarp and endosperm, as seen in figure 3.2) can also be further processed to become Palm Kernel Oil (PKO) (Harun et al., 2013). Additional refining and fractionation of the oil will further produce a different quality of oil such as, refined bleached and deodorised (RBD) palm oil, palm olein, palm stearin, palm fatty acid distillate and biodiesel, among others (Corley & Tinker, 2015). These different palm oil products would have a different function that can be used for various products such as frying oil, component of ice creams, margarine, confectionery fat in chocolate and bakery products (Berger, 2010). A detailed product derivative of palm oil is presented in Figure 3.3. Even with the different derivative products, CPO is still highly valued in international market since it is easier to check for the quality (Corley & Tinker, 2015).

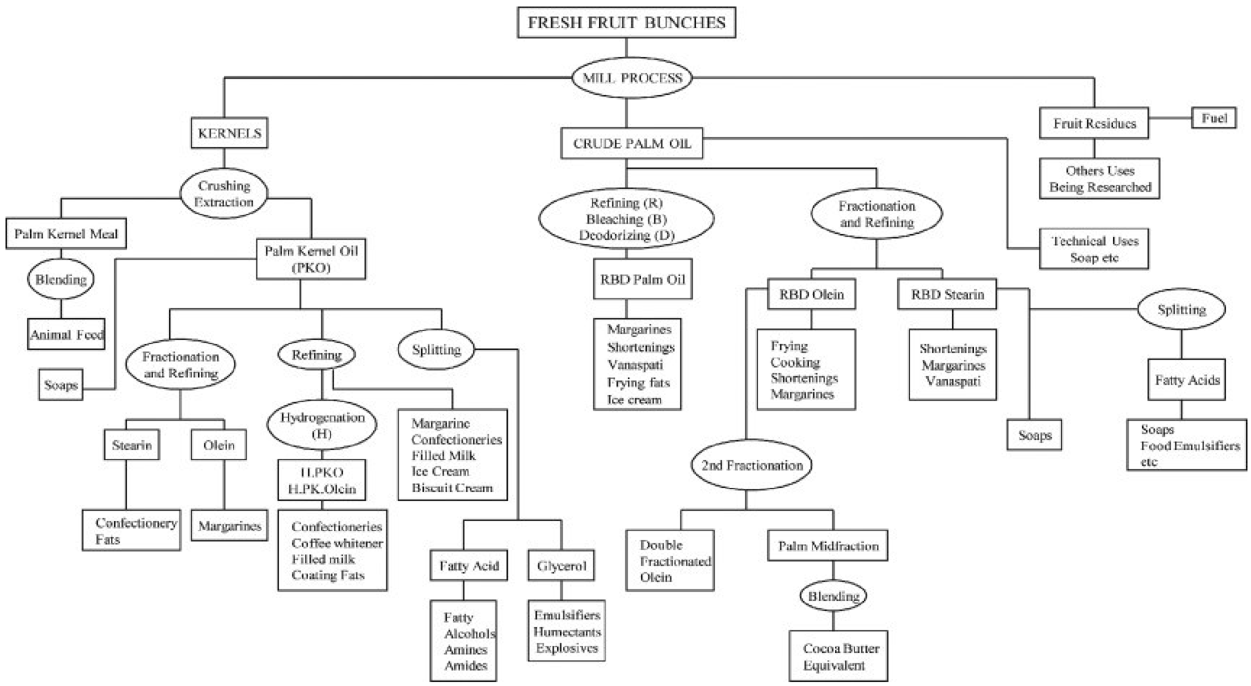

Figure 3.3 Oil Palm Derivative Products (Pantzaris & Ahmad, 2000; Soh, 2012)

In addition, a further processing of the fatty acids in palm oil could form a biodiesel with characteristics similar to diesel fuel (de Souza et al., 2010). As mentioned before, oil palm produces a very high yield of oil per hectare compared to other crops, which makes it attractive as a source of biofuel. Moreover, the market price of palm oil is also cheaper due to the number of quantity produced compared to other vegetable oil crops (Zahan & Kano, 2018). Corley & Tinker (2015) further stated that the biofuel is carbon neutral since it is derived from photosynthesis. However, they also recognised that oil palm biodiesel is also not completely environmental-friendly. Outside of using the palm oil itself, biofuel could also be produced from the biomass and biogas generated from effluent, although the quantity produced is also significantly smaller. A detailed chart of product derived from oil palm can be seen in figure 3.3.

Since 2000, the price for palm oil has fluctuated in a short period but also showed an increasing trend over the years (Corley & Tinker, 2015). This was influenced by the growing demand for palm oil function for food use (Fry & Fitton, 2010) and especially biodiesel (Corley & Tinker, 2015). The other factor contributing to palm oil price is the production cost itself. The harvesting and maintenance of oil palm require a labour-intensive process, which became the main cost component of a palm oil production. The labour price could determine how competitive a palm oil company compared to other players in the industry.

A smaller oil palm farm size of only a few hectares is usually referred as smallholder plantation (Corley & Tinker, 2015). The report by the Committee on World Food Security of the United Nation found the majority of smallholder farmers in Asia only has field below 2 Ha (Swaminathan et al., 2013). Even among the smallholder plantation, there are oil palm farmers who work alone or in small group. In the oil palm industry, there is little advantage for smallholder farmers since the harvesting and nurturing process are fairly simple and doesn't need detailed attention. It is also not economically efficient for smallholder farmers to have their own machinery for palm oil extraction. The common practice for these farmers is to sell their fruit to the nearest mill owned by larger farmer/company. Small oil extraction mill is also popular in Africa and India, with a processing capacity of 1 - 4 ton FFB per hour and oil extraction rate (which is the oil produced divided by the sum of oil produced and known oil losses) of up to 90% as mentioned by Hassan et al. (2016). In comparison, the average oil palm extraction mill could process up to 20 ton of FFB per hour with an oil extraction rate of up to 92% (Corley & Tinker, 2015).

Despite the appeal of palm oil, the overexpansion of land clearing and deforestation due to oil palm in recent years has caused environmental concerns. Clearing a forest for oil palm will damage the biodiversity and result in large emissions of GHG. The impact especially severe for oil palm converted from peat land, as there is further release of CO_2 from oxidation of the peat, which causes additional emission in subsequent years (Oleszczuk et al., 2008). Moreover, some farmers prefer to use fire to clear the forest quickly, which further causes more GHG emissions and other pollution from the process (Paterson & Lima, 2018). However, this impact is not exclusive to oil palm, as any other crop expansion will affect the environment negatively if performed in excessively (Corley & Tinker, 2015)

3.2 Palm Oil and Carbon Market

Palm oil industry has a unique position in terms of GHG balance management since there is an opportunity to net-off their carbon emission with the carbon sequestration potential of the oil palm plantation. Within the replanting timeframe of 25 years, palm plantation established from grassland rehabilitation could net a carbon sink potential of approximately 136 ton CO_2 equivalent/Ha, while plantation established from peatland conversion would net a carbon emission of up to 1,314 ton CO_2 equivalent/Ha (Germer & Sauerborn, 2008).

Within the Kyoto Protocol, several mechanisms through the CDM projects exist for the palm oil industry to gain CER which could be sold as carbon credit. Research in Malaysia suggested that the CDM project in palm oil industry mainly focus on biomass energy produced from palm oil mill effluent (POME), agricultural residue and wood waste, which consist 80% of Malaysia's CDM pipeline in 2015, and methane avoidance projects (Hamzah et al., 2019). Based on the research, challenges for the project from the industry perspective include the cost of registration, certification and CER consultation and verification. Furthermore, the GHG reduction project would be prioritized to reduce the net carbon footprint of the company itself before being traded, unless the company has achieved the sustainability target. However, the research further suggested that sales of carbon credits are seen as having positive economic potential.

An alternative mechanism to gain carbon credit for the forestry sector in general would be to apply REDD+ (Boucher, 2015). However, the application of this mechanism would also mean a trade-off between utilising the land for REDD+ or oil palm plantation. REDD+ could financially outperform oil palm in some conditions, such as in regions with low oil-palm suitability or in areas with high oil palm suitability, but with high carbon price and high carbon stock (Abram et al., 2016). One study showed that a 10-year moratorium in palm oil in Indonesia would result in equivalent emission reductions that could be achieved from price-based instrument at a price of US$3.30–US$7.50/ton CO_2 equivalent (mandatory market) or US$12.95–US$19.45/ton CO_2 equivalent (voluntary market such as REDD+) (Busch et al., 2015).

Abram et al. (2016) found that REDD+ could outcompetes against oil palm under several circumstances, such as in area with low oil palm suitability, area with high carbon sequestration potential or if the carbon price is set at high level. Unfortunately, the circumstances found are specific and not easily reproduceable for all smallholder farmers. Butler et al. (2009) found that oil palm completely outperforms REDD+ in a study case of preserving 10,000 ha forest. The historically low carbon price and the possibility of credit from REDD+ flooding the market are also commonly used as main concerns of why its usage is limited (Boucher, 2015). In conclusion, it will be hard to make REDD+ become financially attractive especially for smallholder farmers, as in both cases, it involves purely abandoning the profit from selling the oil palm FFB.

3.3 Palm Oil Industry in Indonesia

Indonesia is the biggest palm oil producers in the world. Blessed with the ideal climate and vast fertile land, the annual production of palm oil in the country reach up to 26.9 Mt/year in 2012, which consist of more than 50% of the world palm oil production (Corley & Tinker, 2015). Out of this production, around 70% is being exported, while the rest is consumed for domestic usage (Corley & Tinker, 2015; Rifin, 2010).

The oil palm industry mainly comprised of government-owned enterprise, private companies and smallholder farmers. Private companies contributed to the largest palm oil production, followed by smallholder farmers and then government-owned enterprise (Rifin, 2010). Furthermore, smallholder farmers often produce lower yield per hectare compared to private companies, mainly due to the lack of access for palm oil mill and better fertilizer (Corley & Tinker, 2015).

It is common for smallholder farmers to collaborate with private companies through the Nucleus Estate and Smallholder scheme or also known as *Perkebunan Inti Rakyat* scheme, which wasa introduced by the Indonesian government in 1979 (Rifin, 2010). In the scheme, the company will have to develop some percentage of the surrounding area around their oil palm plots (usually called estate or nucleus in the scheme) by developing and planting it with oil palm until it is ready to produce FFB (Steenoven, 2013). The developed area will be called as plasma and will be managed by local smallholder farmers after the maturity phase instead of the Company's employee. The development of the area will be considered as loan for the group of farmers represented by a small-scale union, which they have to repay by selling the FFB produced (usually to the company) throughout the years. The scheme will benefit the farmers by giving them a ready to manage oil palm field, while also giving the company a steady supply of FFB to be processed in their mill. Ideally, the farmers should be able to repay the loan before the replanting cycle of 25 years is over.

Because of their status as the biggest palm oil producer, significant attention is given to the Indonesia's handling of deforestation issue. It is estimated that the palm oil area in Indonesia expanded for 3.7 million hectare throughout the period of 2000-2010 (Corley & Tinker, 2015). Forest fire has also become a recurring problem which stems from burning peatland area to open new plantation field, irresponsible plantation practice, lack of enforcement for unlawful action and also from a natural cause such as the El Nino Southern Oscillation (Tacconi, 2003).

In recent years, Indonesian palm oil export has experienced setbacks in entering international market such as the European Union because of the deforestation issue (Rifin et al., 2020). Several problems were cited as the reason for suspending palm oil import from Indonesia, which include corruption, child labor, violation of human rights, omission of the rights of indigenous people and the loss of biodiversity from deforestation (European Parliement, 2017). Despite its potential, the framework of the Renewable Energy

Directive (a framework used to regulate renewable energy use in the European Union) also phased out CPO as biofuel source due to their high emission level.

To handle these concerns, the Indonesian government implemented several regulations which intend to address the sustainability problem of palm oil industry. Firstly, the government has issued the Indonesian Sustainable Palm Oil (ISPO) standard, an adaptation of the international Roundtable on Sustainable Palm Oil (RSPO) standard which perform as certification for palm oil producers in Indonesia if they manage to comply to the sustainable requirements stated in the standard (Corley & Tinker, 2015). The government has also implemented regulations such as, Government Regulation 71/2014 about Peatlands that cannot be used for planting area, Food Area Preservation Law 41/2009 to prevent excessive conversion from food crops and also the Presidential Instruction 8/2018 which freeze the addition of new oil palm license for three years (Corley & Tinker, 2015; Maskun et al., 2020).

3.4 Smallholder Oil Palm Farmers in Indonesia

Smallholder oil palm farmers have several disadvantages compared to private companies. They generally have lower yields compared to the big company plantations, mainly due to the high cost of fertiliser and lack of access to capital (Corley & Tinker, 2015). The lack of specific knowledge about good fertilizer applicable to their area is another reason that the farmers get a lower yield.

One of the important components for palm oil production is the palm oil mill. However, small scale palm oil mill is not widely used in Indonesia and is expensive to procure for smallholder farmers. Hence, most of the smallholder farmers will sell their FFB to the nearest palm oil mill, which are usually owned by private company. As not every farmer has fields close to a palm oil mill, this forces them to rely on a middleman (Steenoven, 2013) which would also mean an additional cost for transporting the FFB to be sold.

Another issue plaguing smallholder farmer is about converting area into oil palm field. The legal way to convert the area is by slashing, cutting and nurturing the soil again to establish the land for the next planting cycle. However, it is cheaper and faster to use fire with an estimated cost of only USD 15 per hectare (Purnomo et al., 2018). Even though it is prohibited by the government, this practice is still commonly performed in Indonesia. Maswadi et al. (2018) found that the burning behaviour of community land is influenced by income, land productivity, level of knowledge, awareness of the burning of land, and activeness of local organization among other reasons. The incentive to use cheaper method to open a new field is also apparent since oil palm will need 3 to 4 years to reach its maturity stage and able to produce sales-grade FFB (Corley & Tinker, 2015).

As 70% of Indonesian palm oil production is exported (Rifin, 2010), most of the companies that purchase smallholder farmers' FFB are engaged in export practice. With the international pressure for a more sustainable palm oil practice, smallholder oil palm farmers must also adapt to it by implementing the ISPO/RSPO certification. Hutabarat et al. (2019) explained that "*certification puts independent smallholders in a less advantageous situation given limited economies of scale, agronomic constraints, and institutional barriers*". However, they found that farmers engaged with the plasma scheme will find it easier to implement the certificate as they are supported by the nucleus company. Farmers planning to apply for ISPO and RSPO are also prohibited to expand their area by burning or encroaching peatland (Hutabarat et al., 2019; Purnomo et al., 2018).

Despite the adverse circumstances of smallholder oil palm farmers, oil palm is still popular among smallholder farmers due to its high demand. Oil palm farmers required less care and detailed attention compared to other crops such as coffee and cocoa (Corley & Tinker, 2015). Oil palm has also been considered as the most profitable land use choice within the time frame of 25 years compared to popular crops like rice or rubber due to the high yield and low labour cost (G. Liu et al., 2020). Oil palm cultivation has higher labour productivity, but lower land productivity compared to rubber plantation (Clough et al., 2016). Based on economic consideration alone, growing oil palm is the most compelling options for smallholder farmers.

Chapter 4 Voluntary Carbon Market Methodology

In Chapter 2, we have known that the pilot project of carbon market scheme in Indonesia will not include the palm oil industry. On the other hand, voluntary carbon market has existed for some time in the form of REDD+ or other smaller scale international carbon offsetting project. One of the sub-research questions in this study is to explore the voluntary carbon credit methodology which could be used by smallholder oil palm farmers in Indonesia to gain carbon compensation. This chapter briefly explains some of the available voluntary carbon market methodology from Plan Vivo Foundation, The Gold Standard, and Verra.

4.1 Existing Voluntary Carbon Market Methodologies

Voluntary carbon market consists of a wide array of selections from the big standard like Verra or The Gold Standard to a smaller niche market (Donofrio et al., 2020). The flexible nature of the market put room for innovation, which provides opportunity to experiment for small-scale farmers. Unlike big oil palm companies, diversification or changing direction is more easily implemented for smallholder farmers if there is a financial incentive to do so. The smaller scale gives an advantage in having special and customised care for the field (Corley & Tinker, 2015).

In general, the principle of voluntary carbon market is to give compensation based on the improvement on carbon sequestration or reduced carbon emission according to the agreed baseline (Wise & Cacho, 2005). Some markets also give compensation based on other indicator, such as biodiversity protected or value-added given to local stakeholders, among others (Woodside, 2016). Table 4.1 summarises some of the methodology and approaches that are used in agriculture and forestry voluntary carbon market. The tables are summarised based on the methodologies published by Plan Vivo Foundation, The Gold Standard, and Verra as the biggest voluntary carbon market (Plan Vivo, 2020; The Gold Standard, 2021; Verra, 2021).

Based on the methodologies presented in table 4.1, this research will use the Small-Holder Agriculture Monitoring and Baseline Assessment (SHAMBA) from Plan Vivo foundation as the basis for the methods used. The reason is because the SHAMBA project is aimed for smallholder farmers with methodologies by planting tree or performing agroforestry project which could increase the carbon stocks in the area (Plan Vivo, 2015). Other than that, the other methodologies available are not suitable for the objective of the research to find alternative commodities for oil palm since they mostly involve improved sustainable farming management, such as optimal fertiliser usage and tillage management. One of the methodologies from Verra also involved converting low-productive forest to high-productive forest. However, this method is aimed more to rehabilitate logged and degraded rainforest rather than agriculture farm like oil palm. In the next section, further details of the SHAMBA methodologies will be explained.

Carbon Standard	Methodology Name	Target Project	Brief Summary
Plan Vivo	SHAMBA methodology	Smallholder Farm	Quantifies the changes in carbon stocks in soils, vegetation as well as GHG emissions from tree planting, agroforestry, and agricultural interventions.
Plan Vivo	Estimation of Climate benefits from REDD in community-managed forests	Community Forest	Quantifies the reduction of GHG emission by implementing forest management practices to avoid deforestation and forest degradation. Baseline is based on if the area is not brought under effective community management.
The Gold Standard	The Gold Standard Low Tillage Methodology	Agriculture Farm	Quantifies the increase of soil organic carbon compared to baseline year by implementing improved tillage practices.
Verra	Adoption of Sustainable Agricultural Land Management	Agriculture Area	Quantifies the enhancement of aboveground, belowground and soil-based carbon stocks of agricultural areas by applying sustainable management practices.
Verra	Quantifying N2O Emissions Reductions in Agricultural Crops through Nitrogen Fertilizer Rate Reduction	Agriculture Area	Quantifies the reduction of N2O by the application of best practice management through optimal fertilizer usage.
Verra	Methodology for Improved Forest Management through Extension of Rotation Age	Forest Area	Quantifies the GHG emission reduction and the increase of carbon stock by extending the rotation age before harvesting.
Verra	Methodology for Conversion of Low-productive Forest to High-productive Forest	Forest Area	Quantifies the GHG emission reduction by rehabilitation of previously logged forest.

Table 4.1 Forest and Agriculture Carbon Project Methodologies Summary

4.2 SHAMBA Methodology

SHAMBA calculates the change in carbon stocks in the soil, vegetation and also GHG, and then compares it to the baseline scenario to determine the climate benefit (Plan Vivo, 2015). The tools are developed by Plan Vivo with collaboration from the University of Edinburgh and support from the Climate Change, Agriculture and Food Security research program and the Ecosystem Services for Poverty Alleviation. There are several applicability conditions that needs to be fulfilled before a project is eligible to implement SHAMBA, including no negative alteration of the areas, the project must involve tree planting and that the project should not increase the GHG emission in both the project area and the surrounding area. Project activities also cannot be carried out in areas where tree planting is planned in the baseline scenario. The full list of these conditions can be seen in table 4.2.

SHAMBA has been implemented in Plan Vivo project in Uganda, Mexico and Mozambique (Plan Vivo, 2021). The ongoing projects are related to agroforestry, forest management and afforestation/reforestation, which involved smallholder families as the participants. Plan Vivo's role in the project is to perform the MRV process annually to measure the climate benefit from the project, then generate Plan Vivo Certificates (PVC). PVC is sold either directly by the project coordinator or through a trusted reseller endorsed by Plan Vivo to end-buyer, which could range from individual to companies. The price of PVC for end-buyer is ranging from US$15 to US$30.

SHAMBA Methodology applicability condition	
1	Project activity areas have not been negatively altered, prior to the start of project activities for the purpose of increasing climate benefits
2	The baseline land use scenario in the project activity areas can be modelled using the SHAMBA tool, or can be conservatively assumed to be zero (for example if the baseline land use is expected to result in declining carbon stocks in soil and biomass)
3	Project activities involve tree planting, agroforestry, or conservation agriculture
4	Project activities will not increase GHG emissions or reduce carbon stocks in or around the project area, relative to the baseline scenario, by changing: a. Livestock management; b. Manure application; c. External organic inputs such as mulch; d. Tillage, leaching or erosion of soil; or e. Management of existing trees and woody vegetation
5	Project activities are not carried out in areas where tree planting is planned in the baseline scenario
6	Soils in the project area are not waterlogged or flooded regularly and are at least 30 cm deep.

Table 4.2 SHAMBA Conditions (Plan Vivo, 2015)

Based on the methodology guideline (Plan Vivo, 2015), the carbon pools that is included in the SHAMBA calculation are above-ground woody biomass, below-ground woody biomass and soil organic carbon. The total carbon captured or emitted is presented as ton CO_2 equivalent per hectare (tCO_2e/ha). Both in the project area and baseline area, the annual carbon stored or emitted is calculated based on the emissions from biomass burning, nitrogen inputs to soils and the use of nitrogen fertilisers in addition to the change to woody biomass and soil organic carbon. The expected annual climate benefit is calculated by subtracting the total carbon captured or emitted from the project to the baseline. Annual climate benefit is defined as the carbon stored or the emission removed compared in the project compared to the baseline scenario. The smallholder farmers then will be compensated based on this climate benefit after it has been converted to PVC.

For SHAMBA to be implemented for an oil palm field, it must fulfil the applicability condition. One of the conditions that needs to be especially considered is that the area should not be negatively altered for the purpose of increasing climate benefits prior to the start of the project (condition 1). This means no other carbon project should be implemented in the area before the start of the project. Additionally, project activities are not carried out in areas where tree planting is planned in the baseline scenario. Therefore, the project could not be carried out if the farmers intended to continue planting the field with their previous commodity, in this case, oil palm trees. SHAMBA project could only be implemented when the oil palm field is empty after the regular replanting process, after the plant is not economically profitable to be kept.

Chapter 5 Alternative Crop Plantation for Smallholder Oil Palm Farmers in Indonesia

The second sub research question in this research is to investigate potential commodities options suitable in Indonesia which have a higher carbon sequestration than oil palm plantation. A more feasible option for smallholder farmers to gain financing from voluntary carbon market is by substituting the oil palm field into another productive commodity with higher carbon sequestration potential. With a productive commodity, the farmers will not lose much opportunity cost from selling palm oil since they could still have a steady stream of income from selling the commodity. In addition, they still have the chance to gain additional income from the voluntary carbon market, while also reducing the environmental problems from oil palm.

To explore other potential commodities, a summary of carbon stored in some of the common perennial crops in Indonesia is presented in table 5.1. The carbon stored in those crops are compared to oil palm at the same age. In addition, table 5.1 also presents the information of optimal productive planting cycle of the crop. One planting cycle is defined as the phase from land preparation of the area (including removal of plantation from previous cycle) until just before the plantation needs to be removed for the next cycle.

Perennial crop (sorted by the area planting age)	Study location	Carbon stored in aboveground biomass (tCO_2/Ha)	Source	Optimal productive planting cycle	Lifespan reference
Oil Palm - 7 years old	Ghana	21.7	(Kongsager et al., 2013)	25 years	(Woittiez, 2019)
Acacia Mangium - 9 Years Old	East Kalimantan	62.1	(Syahrinudin, 2005)	9 years	(Syahrinudin, 2005)
Oil Palm - 10 years old	Sumatra	37	(Syahrinudin, 2005)	25 years	(Woittiez, 2019)
Rubber - 12 years old	Ghana	61.5	(Kongsager et al., 2013)	30 years	(Munasinghe & Rodrigo, 2017)
Oil Palm - 16 years old	Ghana	28	(Kongsager et al., 2013)	25 years	(Woittiez, 2019)
Oil palm - 20 years old	Sumatra	43.1	(Syahrinudin, 2005)	25 years	(Woittiez, 2019)
Cocoa - 21 years old	Ghana	65	(Kongsager et al., 2013)	30-40 years	(Vekua, 2013)
Oil Palm - 23 years old	Ghana	45.3	(Kongsager et al., 2013)	25 years	(Woittiez, 2019)
Orange - 25 years old	Ghana	76.3	(Kongsager et al., 2013)	25-30 years	(Izamuhaye, 2008)
Oil palm - 30 years old	Sumatra	56.6	(Syahrinudin, 2005)	25 years	(Woittiez, 2019)
Rubber - 44 years old	Ghana	213.6	(Kongsager et al., 2013)	30 years	(Munasinghe & Rodrigo, 2017)

Table 5.1 Stored Carbon in Different Perennial Crop

Based on the table, there are several crops that have potential carbon sequestration higher than oil palm:

- At 9 years old, Acacia Mangium (62.1 tCO_2/Ha, Syahrinudin, 2005) has almost the double of carbon stored compared to oil palm tree at 10 years old (37 tCO_2/Ha, Syahrinudin, 2005). However, Acacia tree has much faster planting cycle of only 9 years (Syahrinudin, 2005) compared to oil palm of 25 to 30 years (Woittiez, 2019). This research will focus to investigate crops with similar planting cycle to oil palm.

- Rubber at 12 years old stored higher carbon compared to oil palm (61.5 tCO_2/Ha, Kongsager et al., 2013), even compared to oil palm aged 16 and 20 years old (Kongsager et al., 2013; Syahrinudin, 2005). Rubber also has a long productive planting cycle of 30 years (Munasinghe & Rodrigo, 2017).
- Cocoa is another plan that stored higher carbon compared to oil palm. At 21 years old, cocoa stored 65 tCO_2/Ha compared to only 43.1 tCO_2/Ha in 20 years old oil palm. Rubber has the production planting cycle of 30 years (Vekua, 2013).
- The last crop that is investigated in this research is orange, which has 76.3 tCO_2/Ha of carbon stored at 25 years old (Kongsager et al., 2013) compared to 56.6 tCO_2/Ha in 30 years old oil palm (Syahrinudin, 2005). Orange has the optimal productive planting cycle of 25 to 30 years old (Izamuhaye, 2008).

Based on this comparison, it can be concluded that rubber, cocoa, and orange are the plants with similar planting cycle as oil palm, which potentially could have higher carbon biomass. These plants can be considered as an alternative for smallholder oil palm plantation farmers that are considering changing their main commodity.

Chapter 6 Methods

In previous chapters, this research has performed literatures review to answer the sub-research question presented in chapter 1. The result from the literature review is used as the basis to determine how this research will adapt the model to answer the main research question. A summary of methods performed corresponding with the research question is presented in table 6.1. In the following section, the methods to answer the main research question of commodity which could financially outperform oil palm after considering the voluntary carbon market potential will be described.

	Research Question	Methods	Chapter
Sub-Research Question 1	Which voluntary carbon credit methodology can be used to gain carbon compensation for smallholder oil palm farmers in Indonesia?	Literature Review	Chapter 4
Sub-Research Question 2	What are the potential commodities options suitable in Indonesia which have a higher carbon sequestration than oil palm plantation?	Literature Review	Chapter 5
Main Research Question	Which commodity could financially outperform oil palm in smallholder farmers in Indonesia with consideration to voluntary carbon market potential?	Hartman Optimal Forest Resources Model	Chapter 7

Table 6.1 Methods Summary

6.1 Optimal Forest Resources Modelling

Forests present a unique case for natural resources management. Aside from timber, there are other benefits that could be reaped such as watershed protection, erosion control, habitats for other special and climate regulation through carbon sequestration (Touza et al., 2008). Furthermore, forest can provide benefits for several years before being depleted. As renewable resources, a depleted forest can be nurtured and replanted to restore its original function. Due to their unique nature, several economic models try to translate the optimal way for forest management and harvesting into a mathematical equation. The following section will briefly discuss Faustmann and Hartman model as the optimal forest harvesting economic model (Touza et al., 2008).

A. Faustmann Model

The Faustmann formula (Faustmann, 1849) identified at what age the forest should be harvested or being cut to maximise the return of the forest. (Touza et al., 2008). One of the assumptions in the model is that the forest is evenly aged and planted with a monotonous type of plant (same grow rate).

The mathematical notation used in the formula are:

J = Net present value of the bare land in one planting cycle
w = planting cost
e^{-rt} = continuous time discount factor
r = market interest rate
t = the age of the forest at the time of the cut
V(t) = the stand/timber value as a function of the forest age.

The model begins as a simple formula where the value of the bare land per hectare in one planting cycle, **J**, is equal to the timber value at the age of its cut, **V(t),** deducted by the planting cost per hectare, **w**. This assumes that the planting cost is a one-off expense that is performed at the beginning of the planting period, while it will take several years for the forest to grow and give the optimal timber value. To address the value in time difference, continuous time discount factor, $\mathbf{e^{-rt}}$, will be used at annual market interest rate, **r**. Based on this information, the model for one planting cycle will be:

$$\boldsymbol{J = -w + e^{-rt}V(t)}$$

As the farmers will expect to continue cutting each time the timber reaches the optimum value, the cycle will go on until an unknown time, which transforms the model as follows:

$$\boldsymbol{J = -w + e^{-rt}V(t)e^{-rt} + [-w + e^{-rt}V(t)]e^{-r2t} + [-w + e^{-rt}V(t)] \ldots}$$

$$\boldsymbol{J = \sum_{i=o}^{\infty} e^{-rit}[-w + e^{-rt}V(t)]}$$

Using the theorem of geometric series, the model can be further simplified as follow:

$$\boldsymbol{J = \frac{-w + e^{-rt}V(t)}{1 - e^{-rt}}}$$

B. Hartman Model

The Faustmann formula did not include the environmental or ecosystem value of the forest, as it only focused on the value of the timber. Many of the environmental value does not have a market price, which makes it hard to estimate based on commercial price. One of the model that tried to include the stand environmental value is the Hartman model (Hartman, 1976). Hartman expanded upon the concept of optimal forest harvesting rotation set by Faustmann and added stand environmental value which depend on stand age.

The mathematical notation used in the formula are as follows:

H	= Environmental value of the land
A(s)	= function of environmental value over s
$\mathbf{e^{-rs}}$	= continuous time discount factor
r	= market interest rate
s	= integration variable
t	= rotation period

In one rotation, the present value of environmental values of the forest over the years until the time of the cutting, **t**, is defined as the integration of the function of environmental value, **A(s)**, impacted by the continuous time discount factor $\mathbf{e^{-rs}}$, which is translated as follow:

$$\boldsymbol{H = \int_0^t A(s)e^{-rs}ds}$$

Similar to the hartman model, the rotation will keep on going until unknown time, as follows:

$$\boldsymbol{H} = \int_{0}^{t} \boldsymbol{A(s)e^{-rs}ds} + \boldsymbol{e^{-rt}} \int_{0}^{t} \boldsymbol{A(s)e^{-rs}ds} + \boldsymbol{e^{-rt}} \int_{0}^{t} \boldsymbol{A(s)e^{-rs}ds} \dots \infty$$

Using the theorem of geometric series, the model can be further simplified as follows:

$$\boldsymbol{H} = \frac{\int_{0}^{t} \boldsymbol{A(s)e^{-rs}ds}}{\boldsymbol{1 - e^{-rt}}}$$

To gain the total value of the land, $\mathbf{J_H}$, which includes the timber and the environmental value, the model can be combined with the Faustmann formula to get the final formula as follows:

$$\boldsymbol{J_H} = \frac{\boldsymbol{-w + e^{-rt}V(t) + \int_{0}^{t} A(s)e^{-rs}ds}}{\boldsymbol{1 - e^{-rt}}}$$

6.2 Research Model

To measure the performance of different commodity, this research will adapt the Hartman's model (1976) to calculate the net present value for forest in an optimal harvesting rotation while also incorporating modified SHAMBA methodology as determined in chapter 4. Performance of the commodity is defined as the net present value of the benefit gained in the project from the first day the project started until it is finished. This research defines a finished project as when the commodity is not economically performing to continue being harvested, *T*. Therefore, the performance of the commodity is the sum of the present value of the benefit gained throughout the year. In the SHAMBA methodology, the benefit is determined in each year, so this research will use discrete time model to calculate the present value where $\boldsymbol{\alpha}$ represent the discount rate.

$$\boldsymbol{G_{NPV} = G_0 + \frac{G_1}{(1+\alpha)} + \cdots + \frac{G_T}{(1+\alpha)^T}}$$

The net benefit at year 0, G_0, represents the initial cost or investment cost that needs to be performed to get the project started. This could also include the planting cost, which is the initial cost of preparing the land at the beginning of the commodity harvesting cycle, which includes activities such as land clearing, seed purchase, land nurturing among others.

The value of the land at year t, G_t, is the sales revenue at year *t*, V_t, and the carbon revenue at year *t*, A_t.

$$\boldsymbol{G_t = V_t + A_t}$$

The sales revenue at year *t*, V_t, is obtained from the sales of the commodity subtracted with cost of maintaining the commodity each year, with basic formula as follows:

$$\boldsymbol{V_t = q_t \cdot p_t - c_t}$$

Where:

q_t = the commodity quantity sold at year t. This will be determined by the production growth model of each commodity.
p_t = the commodity price for each kg of the commodity sold
c_t = the cost necessary to maintain the commodity, which could include nurturing costs such as the yearly labour cost, fertilizer cost, pesticide and insecticide purchase as applicable.

The carbon revenue, A_t, is determined as the revenue gained from the sales of carbon credit at year t. In this research, we use the basic calculation of the SHAMBA formula where carbon credit is calculated based on the change of the carbon stored in the project area compared to the estimated change of carbon stored if the project is not started (baseline area). Different from SHAMBA, this research does not include the emission generated from nitrogen input, fertiliser and potential biomass burning and will focus only on the potential carbon stored in the plant biomass. The carbon stored is affected by commodity growth model as depending on the planting phase, each commodity will store different carbon stock each year. The formula determined is as follows:

$$\boldsymbol{A_t} = \boldsymbol{k_t} \cdot (\Delta\boldsymbol{m_t} - \Delta\boldsymbol{b_t})$$

Where:

k_t = the price of carbon per kg of carbon stored
Δm_t = change of the carbon stored in the project area
Δb_t = estimated change of the carbon stored in the baseline area

Microsoft excel is used as the software to calculate the result from the model. The calculation steps in the software are as follow:

1. Calculate the sales revenue (V_t) and the carbon revenue (A_t) of each commodity until their optimal age (T)
2. Calculate the present value of the benefits in each year (G_t)
3. Calculate the net present value by adding the present value of the benefits until year T and subtracting it with the initial cost (G_0)
4. Compare the result of the net present value for each commodity

Additionally, there are several assumptions for the model specification used in this research. These assumptions are presented in table 6.2. Research will be performed fully using secondary data from past research and publication. Further explanation about the data collection is described in chapter 7.

No	Assumption	Justification
1	The project is performed in Indonesia	Research objective is intended for smallholder farmers in Indonesia.
2	The project area is assumed to be 1 ha of land	One hectare is the common smallholder farmers land size in Asia (Swaminathan et al., 2013).
3	The commodity planted in the project is homogenous	Research objective is to find alternate commodity for oil palm farmer.
4	The area that is involved in the project is a former oil palm area in replanting phase (usually after 25-30 years of planting. This means the area is already cleared of oil palm tree.	One of the applicability condition for SHAMBA mentioned that project cannot be carried in areas where tree planting is planned in the baseline scenario (Plan Vivo, 2015). Therefore, the project assumed that the field will be left alone after the replanting.
5	Field has not been altered before the start of the project for the purpose of increasing climate benefits. No other carbon credit project has been implemented in the area.	One of the applicability condition for SHAMBA (Plan Vivo, 2015).

Table 6.2 Assumptions Used

6.3 Research Scenario

In chapter 5 this research has found that the potential alternative for oil palm commodity if the farmers also consider carbon revenue performance are orange, rubber and cocoa. The reason being that because those commodities have higher potential carbon sequestration compared to palm oil. This indicates that the commodities can store more carbon in the farm area, which will also mean more carbon credit compensation according to the SHAMBA methodology. This research will focus on investigating the performance of cocoa and rubber, as both commodities are popular to be exported from Indonesia. The scenario that is calculated is presented in table 6.3.

Commodity	Financial Performance	Carbon Revenue Performance	Combined Performance
Oil Palm	✔	✔	✔
Cocoa	✔	✔	✔
Rubber	✔	✔	✔

Table 6.3 Model Scenario

Chapter 7 Data Collection and Input

The data for this research will be collected based on the past research and publications that have been conducted for oil palm, cocoa, and rubber. Data collected from past research of the commodity will include the planting costs, nurturing costs, growth model, optimal harvesting cycle, and carbon stock per year. In the following sections, the source for the data used in the research will be explained. This financial performance in this research will be expressed in Indonesia's currency, Rupiah. If the data source is expressed in currency other than Rupiah, it will be converted with the applicable rates as of 31 December 2020 using Indonesia's central bank rate (Bank Indonesia, 2021).

7.1 Initial cost (G_0)

The initial cost for all scenarios will be the same. Initial cost represents the cost to set up the area, so it is prepared for the project. In this research, it is assumed that the area is a former oil palm field area that has been emptied as part of the replanting cycle every 25 years, with estimated cost of US$ 456/Ha (Rp 6.40 million/Ha) (Svatoňová et al., 2015). In addition to that, there are also administration cost related to the carbon credit project registration. Based on Plan Vivo's website (Plan Vivo, 2021), the registration fee is at minimum US$ 1,000 (Rp 14.03 million) with project design review of US$ 1,800 (Rp 25.26 million). Unlike the replanting cost, the initial cost for carbon revenue is a fixed cost which is not related to the hectare of area involved. The initial cost will be separated between cost related to setting up the plantation and the cost to join the carbon credit scheme as presented in table 7.1.

	Original Currency	**Currency**	**IDR**	**Source**
Initial Cost for Sales Revenue (G_{V0})				
Replanting Initial Cost	456	USD	6,399,723	Svatoňová et al., 2015
Initial Cost for Carbon Revenue (G_{A0})				
Registration Fee	1000	USD	14,034,480	Plan Vivo, 2021
Project Design Review	1800	USD	25,262,064	Plan Vivo, 2021

Table 7.1 Initial Cost

7.2 Discount rate (α)

Discount rate represents the rate of return used to discount future cash flows back to their present value. In this research, the interest rate from Indonesian government bond will be used as the discount rate. It represents the most risk-free investment that the smallholder farmers in Indonesia could obtain. Historically, the yield rate for 30 years Indonesian government bond at the end of 2020 ranges from 6.9% to 7% (Investing, 2021; Market Watch, 2021; Trading Economics, 2021; World Government Bonds, 2021), therefore this research will use 7% as the discount rate.

7.3 Project period (T)

All commodities are assumed to be economically productive until 30 years old (Munasinghe & Rodrigo, 2017; Vekua, 2013; Woittiez, 2019).

7.4 Price of the commodity (p)

As smallholder farmers, all commodities in this research are assumed to be sold in raw material without further processing. The price of the commodity in this research represents the market price as of December 2020, which is presented in table 7.2.

Commodity	Price	Source
Oil palm FFB	Rp 1,686.19/kg – Rp 1,980.59/kg depending on the planting age	Plantation division of North Sumatera government, Indonesia (Dinas Perkebunan Sumatera Utara, 2020)
Natural rubber	US$ 1.49/kg (Rp 20,911.4/kg)	Rubber Association of Indonesia (Gapkindo, 2021)
Cocoa beans	US$ 2.12/kg (Rp 29,697/kg)	Ministry of Trading Indonesia (Kementerian Perdagangan Indonesia, 2020)

Table 7.2 Commodity Price

7.5 Production of the commodity (q)

Each commodity has different yield rate each year. For example, oil palm would not yield FFB fruit in the first four year. This research use growth model from other research and publication to determine the yearly yield rate of the commodity.

a. Oil Palm FFB
   It is assumed that the tree density in the oil palm area is 138 palm/ha (Ni'matul Khasanah et al., 2015), with production rate as defined by (Fitrianto et al., 2017) presented in table 7.3.

No	Stand Age	Average Bunch/trees (Kg/6 months)	Average Bunch/trees (Kg/year)
1	0-3	0	0
2	4-8	68.77	137.54
3	9-14	109.08	218.16
4	15-25	73.91	147.82
5	25-30*	65.448	130.896
*estimated to be 60% of optimal production (Woittiez et al., 2017)			

Table 7.3 Oil palm production rate

b. Natural Rubber
   For natural rubber, this research uses the productivity rate based on the research by Supriadi et al. (2018) in a rubber plantation in Lampung, Indonesia, as presented in table 7.4.

Age	Productivity (ton/ha/year)	Age	Productivity (ton/ha/year)
6	1.07	19	1.68
7	1.74	20	2.1
8	1.93	21	1.89
9	2.34	22	1.68
10	2.52	23	1.47
11	1.68	24	1.47
12	1.68	25	1.89
13	1.93	26	1.69
14	2.1	27	1.47
15	2.18	28	1.26
16	1.96	29	1.05
17	1.96	30	0.84
18	1.68		

Table 7.4 Natural rubber productivity rate

c. Cocoa Bean
For cocoa productivity rate, this research uses the cocoa yield model estimation developed by Obiri et al. (2007) for traditional cocoa plantation in Ghana.

$$\boldsymbol{Q = exp(-1.822 - 0.166t + 3.931\ ln(t))}$$

Where:
Q = Cocoa yield per hectare in kg
t = Years of planting

7.6 Cost of the commodity (c)

a. Oil Palm
For the cost of oil palm farm, this research adapt the data from Houweling (2017) with land preparation cost for four years of US$ 1,055/ha (Rp 14.81 million/ha), yearly operational cost of US$ 1155/ha (Rp 16.21 million/ha) and fixed cost of US$ 148/ha (Rp 2.08 million/ha).

b. Rubber
Same as oil palm, the rubber farming cost is taken from Houweling (2017) with preparation cost of US$ 181/ha (Rp 14.81 million/ha) and US$ 516/ha (Rp 14.81 million/ha) in year 0 and year 1 , and planting cost of US$ 55/ha (Rp 14.81 million/ha) and US$ 11/ha (Rp 14.81 million/ha) in year 1 and year 2. The operational cost per year is established at the range of US$ 199/ha (Rp 14.81 million/ha) to US$ 705/ha (Rp 14.81 million/ha), with additional cost of transport of US$ 12/ha (Rp 14.81 million/ha) after the trees has produced latex in year 6 or 7. For operation cost, this research will use the average cost from the range described, which is US$ 452/ha (Rp 14.81 million/ha).

c. Cocoa

For cocoa farming cost, the data is obtained from Effendy et al. (2019) which performed research of the average cost of cocoa farming in Indonesia. Based on their research, the average yearly operational cost is Rp 2.87 million for 1.63 ha or Rp 1.76 million/ha. The cost includes the cost of pesticide, fertilizer, pruning and sanitation. In addition to that, there is initial cost of purchasing the cocoa seed of Rp 35.58 million for 1.63 ha or Rp 21.83 million/ha.

7.7 Carbon price (k)

As Plan Vivo is not disclosing publicly the price that the project gained from the carbon credit, this research will use an estimation of the price from Plan Vivo's carbon credit reseller for end customer, as listed in their website. These resellers provide carbon offsetting service where the money gained will be channelled to the related carbon credit project that they support. The summary of the price from reseller is presented in table 7.5 with the average price of Rp 333,802 per ton CO_2. The price listed is based on general carbon offsetting service per ton CO_2 which does not attach specific project to the service.

No	Reseller Website	Price per ton CO_2	Price in Indonesian Rupiah
1	https://co2.myclimate.org/	29 CHF	Rp 461,137.4
2	https://cotap.org/	US$ 15	Rp 210,517.2
3	https://takingroot.org/	CAD$ 30	Rp 328,907.4
4	https://www.primaklima.org/	€15	Rp 258,620.4
5	https://zeromission.myclimate.org/	249 SEK	Rp 409,827.6

Table 7.5 Carbon price for offsetting

7.8 Yearly carbon stored (m)

As explained in chapter 6, the carbon stored for the calculation of the carbon credit is calculated based on the yearly aboveground and belowground (root) carbon for each commodity. To estimate the carbon stored, past research which investigate temporal models for carbon calculation are used. In those research (Ni'matul Khasanah et al., 2015; C. Liu et al., 2017; Smiley & Kroschel, 2008), regression analysis were used based on the actual carbon storage data of plants at different age to develop the temporal model. The summary of the models is presented in table 7.6. Due to the unavailability of the model data, this research use carbon storage model from China for rubber commodity.

Commodity	Carbon Storage Model	Source	Research Location	R^2
Oil Palm	$m = 2.5449t + 5.0007$	(Ni'matul Khasanah et al., 2015)	Sumatra, Kalimantan and Sulawesi, Indonesia	0.8441
Rubber	$m = -0.063t^2 + 6.184t - 31.654$	(C. Liu et al., 2017)	Yunnan, China	0.802 (aboveground) 0.711 (belowground)
Cocoa	$m = 2.0672t + 3.5548$	(Smiley & Kroschel, 2008)	Central Sulawesi, Indonesia	0.81

Table 7.6 Model of Carbon Storage

Where:
m = yearly carbon stored, expressed in ton CO_2
t = planting years

Based on the carbon storage models presented in table 7.6, the value of carbon stored in each year for each commodity can be seen in table 7.7. Both cocoa and oil palm have a constant change of carbon storage throughout the years due to the model used being a linear model. In all of the research referenced (Ni'matul Khasanah et al., 2015; C. Liu et al., 2017; Smiley & Kroschel, 2008) the data observations were made for plantation within the optimal years (0-30 years). Hence, the carbon storage models used in this research are less accurate to predict the carbon storage growth for plantation outside of the age range.

	Oil Palm		**Rubber**		**Cocoa**	
Year	**Carbon Storage model**	**Change of carbon storage**	**Carbon Storage model**	**Change of carbon storage**	**Carbon Storage model**	**Change of carbon storage**
0	5.0007		- 31.65		3.5548	
1	7.5456	2.5449	- 25.53	6.12	5.622	2.0672
2	10.0905	2.5449	- 19.54	5.992	7.6892	2.0672
3	12.6354	2.5449	- 13.68	5.864	9.7564	2.0672
4	15.1803	2.5449	- 7.94	5.736	11.8236	2.0672
5	17.7252	2.5449	- 2.33	5.608	13.8908	2.0672
6	20.2701	2.5449	3.15	5.48	15.958	2.0672
7	22.815	2.5449	8.50	5.352	18.0252	2.0672
8	25.3599	2.5449	13.72	5.224	20.0924	2.0672
9	27.9048	2.5449	18.82	5.096	22.1596	2.0672
10	30.4497	2.5449	23.79	4.968	24.2268	2.0672
11	32.9946	2.5449	28.63	4.84	26.294	2.0672
12	35.5395	2.5449	33.34	4.712	28.3612	2.0672
13	38.0844	2.5449	37.92	4.584	30.4284	2.0672
14	40.6293	2.5449	42.38	4.456	32.4956	2.0672
15	43.1742	2.5449	46.71	4.328	34.5628	2.0672
16	45.7191	2.5449	50.91	4.2	36.63	2.0672
17	48.264	2.5449	54.98	4.072	38.6972	2.0672
18	50.8089	2.5449	58.92	3.944	40.7644	2.0672
19	53.3538	2.5449	62.74	3.816	42.8316	2.0672
20	55.8987	2.5449	66.43	3.688	44.8988	2.0672
21	58.4436	2.5449	69.99	3.56	46.966	2.0672
22	60.9885	2.5449	73.42	3.432	49.0332	2.0672
23	63.5334	2.5449	76.72	3.304	51.1004	2.0672
24	66.0783	2.5449	79.90	3.176	53.1676	2.0672
25	68.6232	2.5449	82.95	3.048	55.2348	2.0672
26	71.1681	2.5449	85.87	2.92	57.302	2.0672
27	73.713	2.5449	88.66	2.792	59.3692	2.0672
28	76.2579	2.5449	91.32	2.664	61.4364	2.0672
29	78.8028	2.5449	93.86	2.536	63.5036	2.0672
30	81.3477	2.5449	96.27	2.408	65.5708	2.0672

Table 7.7 Commodity Carbon Storage Per Year (Ton CO_2 e/Ha)

7.9 Yearly carbon stored in baseline area (b)

The Shamba methodology mentioned that baseline land use scenario can be conservatively assumed to be zero if the expected land use would result in declining carbon stocks (Plan Vivo, 2015). This research assumes that the former palm oil field will not be used for any planting purpose if it is not used for the project, therefore the value of the estimated change of the carbon stored in the baseline area ($\boldsymbol{\Delta b_t}$) is zero (0).

Chapter 8 Financial Performance Comparison Result

In this chapter, the result for the financial performance of the commodities is presented.

	Sales Revenue	Carbon Revenue/cost	Total Benefit
Oil Palm	213.13	-28.65	184.48
Rubber	216.38	-18.91	197.47
Cocoa	64.08	-30.65	33.44

Table 8.1 NPV of the Commodities Benefit (expressed in million Rupiahs)

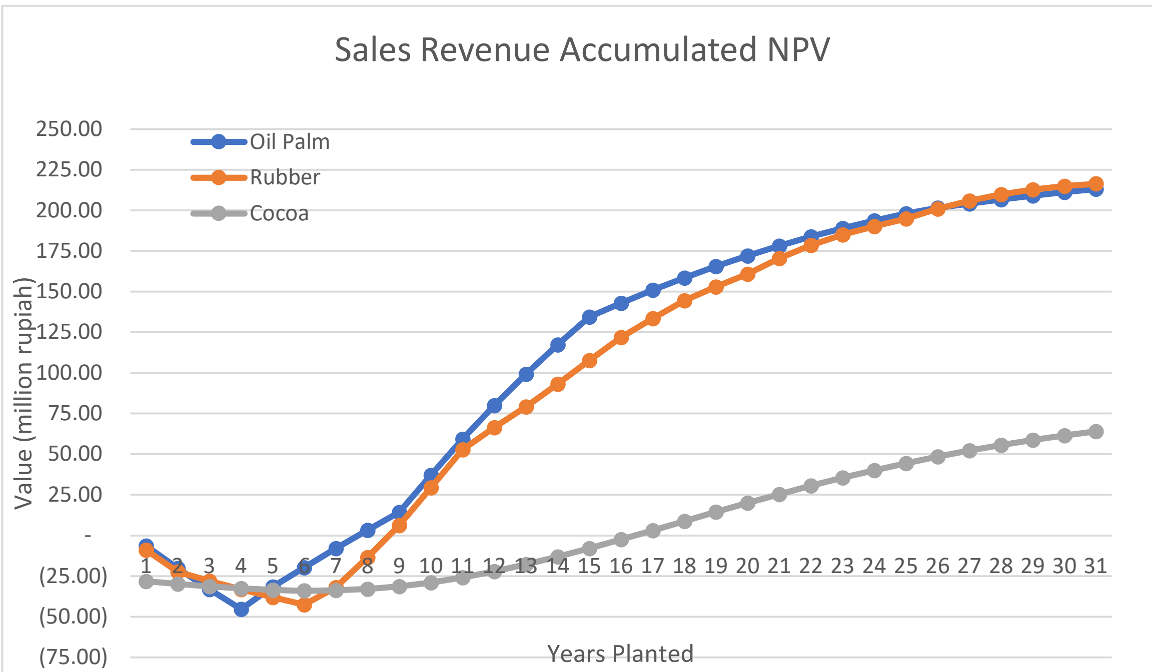

Figure 8.1 Accumulated NPV of The Commodity Sales Revenue

As seen in table 8.1, rubber performs the best out of the three commodities in sales revenue, while cocoa performs the worst and oil palm in the middle. In figure 8.1 it can be seen that initially oil palm performs better, commercially, than rubber. However, in year 26 rubber overtakes the sales revenue of oil palm and starts to be financially more profitable. In terms of carbon revenue, rubber always has higher benefit throughout the year compared to other commodities with oil palm in the second and cocoa in the third, as seen in figure 8.2 and table 8.1. For total revenue, after 30 years rubber also has the best performance compared to oil palm and cocoa. As seen in figure 8.3, rubber overtakes the performance of oil palm at year 20, while cocoa never catches up to the performance of the other commodities.

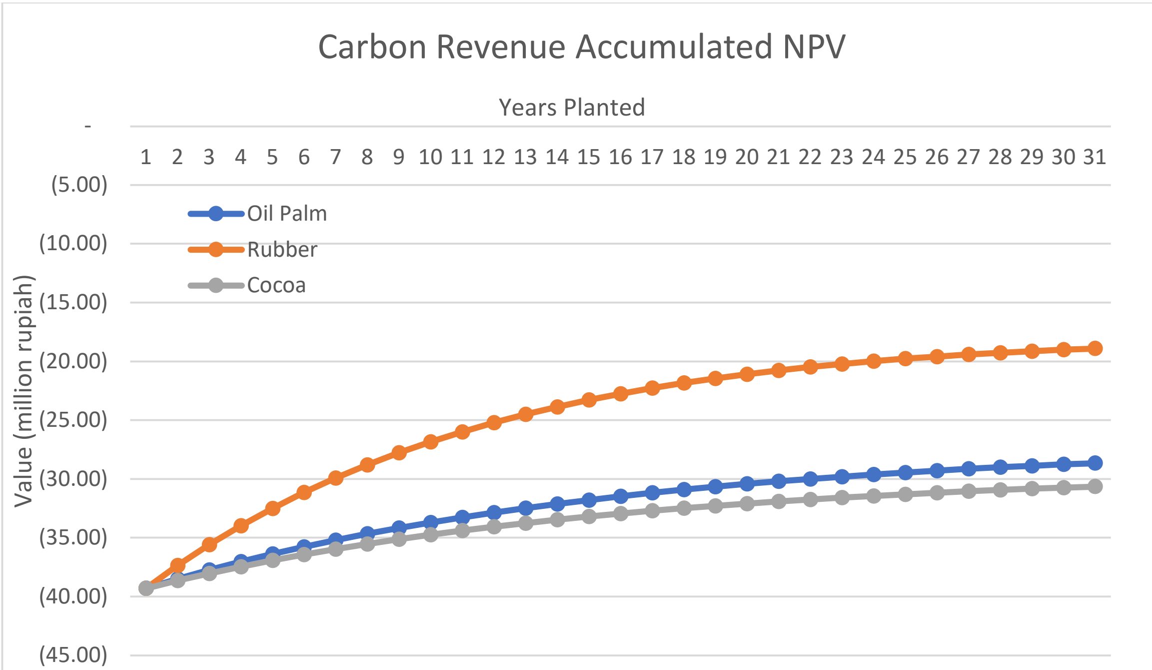

Figure 8.2 Accumulated NPV of The Commodity Carbon Revenue

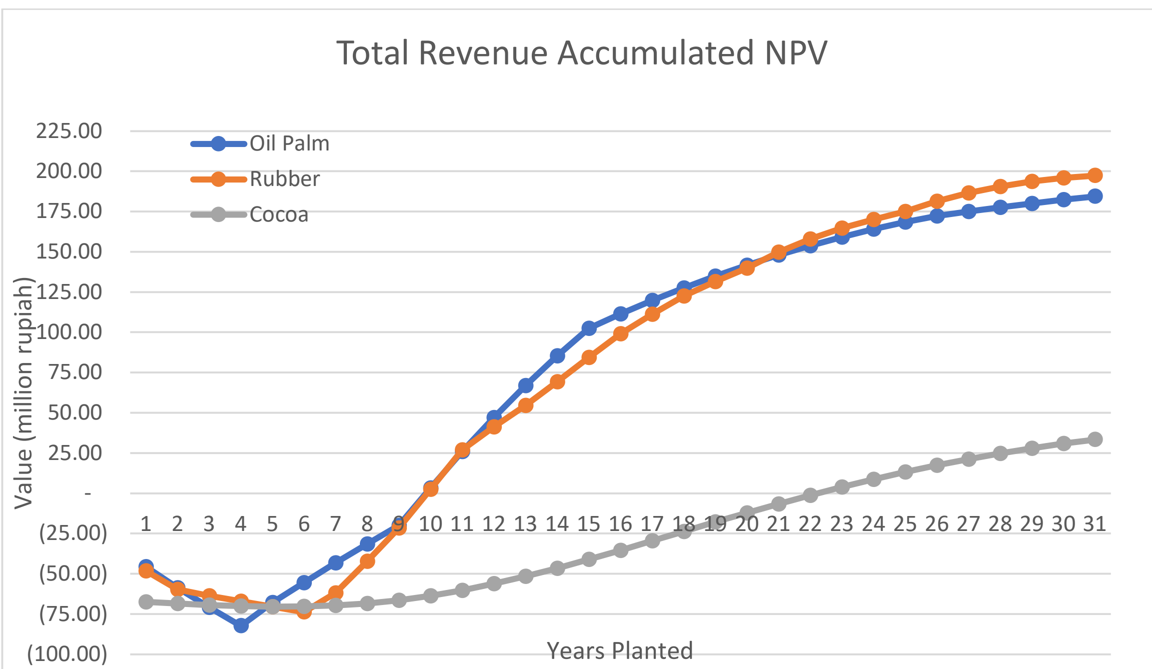

Figure 8.3 Accumulated NPV of The Commodity Total Benefit

According to Swaminathan et al. (2013), one hectare is the common smallholder farmer land size in Asia. However, for 1 hectare of area, the initial cost for registering with the carbon market and the project design review fee (Rp 39.30 million) is higher than the present value of revenue gained for all of the commodities which caused negative carbon benefit (table 8.1). If the project is expanded into 2 hectares, only rubber plantation could barely justify the initial cost for joining the carbon market with present value of the environmental benefit (table 8.2). If expanded further into 4 hectares of project area, both oil palm and rubber have environmental benefit above the initial cost while cocoa still performs better without joining the carbon market.

NPV	2 Ha			4 Ha		
	Sales Revenue	**Carbon Revenue**	**Total Benefit**	**Sales Revenue**	**Carbon Revenue**	**Total Benefit**
Oil Palm	426.26	-18.00	408.27	852.53	3.30	855.83
Rubber	432.75	1.48	434.23	865.51	42.26	907.76
Cocoa	128.17	-22.00	106.17	256.34	-4.69	251.64

Table 8.2 NPV of the Commodities Benefit at 2 Ha and 4 Ha (expressed in million Rupiahs)

This research also performs sensitivity analysis of the discount rate and environmental price to see how a slight change in the value could affect the performance of the commodities. Based on the result in table 8.3, a change of 1% of the discount rate both in positive and negative direction doesn't affect the performance of the commodities. Rubber still performs the best out of the three commodities with oil palm in second place and cocoa in the last place. The same holds true for a change of 10% in environmental price as seen in table 8.4.

NPV	6% Discount Rate			8% Discount Rate		
	Sales Revenue	**Carbon Revenue**	**Total Benefit**	**Sales Revenue**	**Carbon Revenue**	**Total Benefit**
Oil Palm	246.08	-27.48	218.60	185.04	-29.63	155.41
Rubber	253.05	-17.03	236.02	185.42	-20.53	164.89
Cocoa	83.06	-29.70	53.36	48.60	-31.45	17.15

Table 8.3 NPV of the Commodities Benefit at Discount Rate -1% and +1% (expressed in million Rupiahs)

NPV	Carbon Price -10%			Carbon Price +10%		
	Sales Revenue	**Carbon Revenue**	**Total Benefit**	**Sales Revenue**	**Carbon Revenue**	**Total Benefit**
Oil Palm	213.13	-29.71	183.42	213.13	-27.58	185.55
Rubber	216.38	-20.95	195.43	216.38	-16.87	199.51
Cocoa	64.08	-31.51	32.57	64.08	-29.78	34.30

Table 8.4 NPV of the Commodities Benefit at environmental price +10% and -10% (expressed in million Rupiahs)

Based on the result presented, rubber performs the best in every scenario presented, even with adjustment in the project area (table 8.2), discount rate (table 8.3) and environmental price (table 8.4). This is mainly due to the generally accepted optimal commercial age of oil palm of 25 years (Woittiez, 2019) while this research use 30 years of project period, which is the optimal age for rubber and cocoa. After 25 planting years, there is a significant decrease in the productivity of the fruit of oil palm. It is in line with the result of our calculation where, on commercial performance alone, oil palm has the best financial performance up to year 25. However, if the environmental performance is also considered, even at year 25 rubber still performs better than oil palm (figure 8.3).

Chapter 9 Discussion

9.1 Comparison to Past Research

Schwarze et al. (2015) in their study in Jambi found that rubber performed financially better than oil palm based on their sales revenue. According to their interview result, despite the lower income, oil palm is still more popular for smallholder farmers since it is faster to generate income after the initial planting (3 to 4 years for oil palm and 6 to 7 years for rubber). Houweling (2017), also supports the result that rubber is financially more profitable than oil palm based on a study in Kalimantan. Both of this research are in line with what has been found in this research related to the financial performance of rubber and oil palm.

However, research that directly compare the financial performance between cocoa and oil palm is rarer. Khasanah et al. (2020) instead, suggested that agroforestry of intercropping oil palm with cocoa perform better than monoculture oil palm. On the other hand, Niether et al. (2020) found that the yield of the cocoa in agroforestry system is lower than monoculture cocoa by around 25%, but it has total yield (including the other intercropping plant) of 10 times higher. Regarding the cocoa farmers in Indonesia, Effendy et al. (2019) in their study found that the majority of the farmers still perform inefficiently, with potential cost reduction potential from 36% to 76%. As this research uses the secondary data for the operational cost of cocoa from Effendy et al. (2019)'s research, this is in line with the low performance of cocoa compared to other commodity.

On the carbon storage model, both rubber and oil palm are consistent with the result of the study by Kongsager et al. (2013) where rubber has a higher potential of carbon storage compared to oil palm. However, in this research, cocoa performed worse than oil palm in terms of carbon storage growth compared to Kongsager et al. (2013) where monoculture cocoa should have better carbon storage than oil palm. This can be attributed to the fact that this research uses the model by Smiley & Kroschel (2008), where the cocoa plantation in their research is grown under the shade of gliricidia tree, hence it is not completely monoculture.

9.2 Consideration for Smallholder Farmers to Join a Carbon Credit Project

To start a carbon credit project, there are several things that smallholder farmers need to do. One of the most important things is to gain access to the plan vivo foundation or any other voluntary carbon market available. The easiest way to do this is through a middleman or intermediary company that connects the farmers to the carbon market. However, this will also mean additional cost for the farmers for the intermediary.

Despite having the potential to increase the income of the smallholder farmers, the initial cost to register a carbon credit project is also quite high. However, as the cost is a fixed cost (Plan Vivo, 2021) joining a project is more profitable for farmers that have big area to start the project. As seen in chapter 8, it is not financially reasonable for individual farmer with land area of 1 hectare or less to attempt a carbon credit project due to the cost. For the existing projects in Plan Vivo foundation itself, most of the project are performed jointly for several smallholder farmers (Plan Vivo, 2021). By combining several fields together as one project, the initial cost of starting the project can be divided equally to everyone involved. The more area involved in the project, then the more inexpensive the initial cost will be. In this research, for example, the carbon credit could only be profitable for the farmers with area of 2 hectares for rubber and 4 hectares for oil palm.

The farmers also need to consider the price of the carbon certificate. There has been a fluctuation of carbon price in the past few years. For example, in 2019 the average price of forestry and land use carbon offsetting project in voluntary carbon market is US$ 4.3/ton CO_2 (Rp 60,348/ton CO_2) (Donofrio et al., 2020), while the price in EU ETS is € 53.3 (Rp 928,427/ton CO_2) as of July 2021 (Ember-Climate, 2021). The price used in this research of Rp 337,231/ton CO_2 can be considered as conservative price in between the voluntary carbon market price and EU ETS. The Indonesian government itself has set the initial price for the national carbon market pilot project at Rp 30,000/ton CO_2 (Judith, 2021). However, this price is still considered as experimental price since it is too low compared to international carbon price.

To further analyse the carbon price impact, this research performs an additional calculation that measure the carbon price needed to compete with sales revenue. In this scenario, this research assumes that all cost remains the same for the operational of the plantation, except for harvesting cost. Furthermore, it is assumed that the farmers will not sell any of the commodity throughout the planting lifecycle. Using the solver function in Microsoft excel, this research investigates at how much carbon price could each commodity achieve break-even point (zero profit and loss) solely on selling carbon credit. Based on this scenario, it is found that oil palm plantation needs to sell their carbon credit at minimum at Rp 4.13 million/Ton CO_2, rubber plantation at Rp 2,25 million Ton CO_2 and cocoa plantation at Rp 3,48 million Ton CO_2 to cover both the operation cost and the carbon registration cost. Since the price on average is very high of almost 10 times the price used in this research, it is inferred that solely relying on carbon credit is still hard to do for the smallholder farmers.

Finally, the demand of the commodity in the market must also be considered before the farmers shift to plant another commodity. This also holds true for the demand of the carbon certificate itself. If it is possible, the smallholder farmers should perform research to gauge whether the production of new commodity could be absorbed by the market. It also depends on the location of the project itself. As in this research, it is assumed that the farmers only sell raw material of the commodity, the location of potential buyer which process the raw material (for example, palm oil mill or rubber mill) must also be considered. The farther the location of the project to potential buyer, then it will mean there will be additional transportation cost that need to be covered.

9.3 Research Limitation and Suggestion for Future Research

One of the limitations of this research is from the data available. This is especially apparent when different geographical locations of the commodity are chosen for the data. Ideally, all of the cost, growth model and carbon storage model should be sourced from the same geographical location. However, due to the limited data available, some of the data are taken from different location.

For future research, improvement can be made by enhancing the data used through direct observation or interview to smallholder farmers planting different commodity in the same area rather than only relying on past research. Additionally, more variants of the commodity compared would greatly benefit the smallholder farmers by introducing them to more alternative options. For the next step, observing agroforestry performance in voluntary carbon market can be another alternative as it is indicated to perform better than monoculture plants both for commercial performance and carbon storage (Nikmatul Khasanah et al., 2020; Niether et al., 2020).

Chapter 10 Conclusion

The rapid expansion of oil palm plantation in Indonesia could lead to high carbon emission generation. One of the reasons of oil palm popularity is due to its high demand globally and profitable business model. Furthermore, oil palm is regarded as the most efficient vegetable oil producer compared to another crop.

The development of voluntary carbon market has given the chance for other commodity to compete with oil palm by selling their carbon credits. The SHAMBA methods from Plan Vivo foundation can be applied by smallholder farmers in Indonesia to gain additional revenue on top of the commodity sales in the form of carbon credit compensation, as presented in chapter 4. SHAMBA especially can been implemented for agroforestry, forest management and afforestation/reforestation project, which involves several smallholder farmers as the participants.

The SHAMBA methods, compensates smallholder farmers that grow crops with high carbon sequestration. To outperform oil palm which already has high sales performance, it is important for the farmers to find alternative commodities that has higher carbon sequestration potential than oil palm. In this regard, some of the potential alternative commodity to oil palm includes rubber and cocoa as investigated in chapter 5.

In 30 years timeframe, rubber performed financially better than oil palm, both in sales revenue and in carbon revenue as evidenced by the result of the financial performance calculation in chapter 8. However, the farmers must be ready for early capital investment as it will take 6 to 7 years before rubber could be harvested as compared to palm oil of only 3 to 4 years (Schwarze et al., 2015). Cocoa, on the other hand, performs financially worse than rubber and oil palm in both sales and carbon revenue. Khasanah et al. (2020) suggested that agroforestry combining cocoa and oil could perform better than monoculture oil palm plantation.

Despite the potential for additional revenue, there are several things that smallholder farmers must consider before applying to carbon credit project. The high initial cost of registration and the access to contact reputable carbon standard coordinator are some of the important factors to be considered. It is more beneficial to start the carbon credit project with other farmers in the same area so that the high initial cost could be borne together. Furthermore, the farmers must also consider the price fluctuation of the carbon credit and also the demand of the alternative commodity.

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Appendix A Glossary

Abbreviation	Description
AAU	Assigned Amount Units
CDM	Clean Development Mechanism
CER	Certified Emission Reduction
CO2	Carbon Dioxide
CPO	Crude Palm Oil
ERU	Emission Reduction Units
ET	Emission Trading
ETS	Emission Trading System
EU	European Union
FFB	Fresh Fruit Bunch
GHG	Greenhouse Gas
ICER	Indonesia Certified Emission Reduction
JI	Joint Implementation
MRV	Mesurement, Reporting and Verification
NDC	Nationally Determined Contribution
NZ ETS	New Zealand Emissions Trading Scheme
PKO	Palm Kernel Oil
PMR	Partnership for Market Readiness
PVC	Plan Vivo Certificates
RBD	Refined Bleached and Deodorised
REDD+	Reducing Emissions from Deforestation and forest Degradation (REDD) with the addition (+) of the conservation role, sustainable management of forests and enhancement of forest carbon stocks
SHAMBA	Small-Holder Agriculture Monitoring and Baseline Assessment
UNDP	United Nations Development Programme
Verra	Verified Carbon Standard

Appendix B Figure and Table List

Appendix C Currency Data

Currency rates of Rupiah as of 31 December 2020, based on Indonesian Central Bank (Bank Indonesia, 2021).

Currencies	Value	Value
AUD	1	10,716.73
BND	1	10,589.66
CAD	1	10,963.58
CHF	1	15,901.29
CNH	1	2,155.34
CNY	1	2,150.58
DKK	1	2,317.53
EUR	1	17,241.36
GBP	1	18,987.25
HKD	1	1,810.22
JPY	100	13,578.25
KRW	1	12.9
KWD	1	45,946.90
LAK	1	1.51
MYR	1	3,473.02
NOK	1	1,635.45
NZD	1	10,062.72
PGK	1	3,894.57
PHP	1	292.14
SAR	1	3,739.74
SEK	1	1,714.76
SGD	1	10,589.66
THB	1	467.35
USD	1	14,034.48
VND	1	0.61

Appendix D1 Oil Palm Sales Revenue NPV Calculation

Year	Initial Cost - Sales	Quantity sold	Market Price	Fixed Cost	Variable Cost	Sales Revenue/(Cost)	Discounting Factor	PV Sales Revenue	NPV Sales Revenue
Notation	G_{V0}	q	p	c		V_t	(1/1+α)^T		
Unit	Rp	Kg/ha	Rp/Kg	Rp/ha	Rp/ha	Rp/ha	7%	Rp/Ha	Rp/Ha
0	- 6,399,722.88	-	-	-	-	- 6,399,722.88	1	- 6,399,722.88	- 6,399,722.88
1	-	-	-	- 14,806,376.40	-	- 14,806,376.40	0.934579439	- 13,837,734.95	- 20,237,457.83
2	-	-	-	- 14,806,376.40	-	- 14,806,376.40	0.873438728	- 12,932,462.57	- 33,169,920.41
3	-	-	1,686.19	- 14,806,376.40	-	- 14,806,376.40	0.816297877	- 12,086,413.62	- 45,256,334.03
4	-	18,980.52	1,845.26	- 14,806,376.40	- 2,210,968.35	18,006,649.59	0.762895212	13,737,186.76	- 31,519,147.27
5	-	18,980.52	1,951.34	- 18,286,927.44	- 2,210,968.35	16,539,552.11	0.712986179	11,792,472.07	- 19,726,675.20
6	-	18,980.52	2,006.40	- 18,286,927.44	- 2,210,968.35	17,584,619.54	0.666342224	11,717,374.49	- 8,009,300.71
7	-	18,980.52	2,025.47	- 18,286,927.44	- 2,210,968.35	17,946,578.06	0.622749742	11,176,226.85	3,166,926.15
8	-	18,980.52	2,078.59	- 18,286,927.44	- 2,210,968.35	18,954,823.28	0.582009105	11,031,879.73	14,198,805.87
9	-	30,106.08	2,118.59	- 18,286,927.44	- 3,506,942.37	41,988,570.21	0.543933743	22,839,000.14	37,037,806.01
10	-	30,106.08	2,173.10	- 18,286,927.44	- 3,506,942.37	43,629,652.63	0.508349292	22,179,103.03	59,216,909.05
11	-	30,106.08	2,173.10	- 18,286,927.44	- 3,506,942.37	43,629,652.63	0.475092796	20,728,133.68	79,945,042.72
12	-	30,106.08	2,173.10	- 18,286,927.44	- 3,506,942.37	43,629,652.63	0.444011959	19,372,087.55	99,317,130.27
13	-	30,106.08	2,173.10	- 18,286,927.44	- 3,506,942.37	43,629,652.63	0.414964448	18,104,754.72	117,421,884.98
14	-	30,106.08	2,173.10	- 18,286,927.44	- 3,506,942.37	43,629,652.63	0.387817241	16,920,331.51	134,342,216.50
15	-	20,399.16	2,173.10	- 18,286,927.44	- 2,376,220.31	23,666,266.85	0.36244602	8,577,744.22	142,919,960.72
16	-	20,399.16	2,173.10	- 18,286,927.44	- 2,376,220.31	23,666,266.85	0.338734598	8,016,583.38	150,936,544.10
17	-	20,399.16	2,173.10	- 18,286,927.44	- 2,376,220.31	23,666,266.85	0.31657439	7,492,134.00	158,428,678.10
18	-	20,399.16	2,173.10	- 18,286,927.44	- 2,376,220.31	23,666,266.85	0.295863916	7,001,994.40	165,430,672.50
19	-	20,399.16	2,173.10	- 18,286,927.44	- 2,376,220.31	23,666,266.85	0.276508333	6,543,920.00	171,974,592.49
20	-	20,399.16	2,173.10	- 18,286,927.44	- 2,376,220.31	23,666,266.85	0.258419003	6,115,813.08	178,090,405.57
21	-	20,399.16	2,168.42	- 18,286,927.44	- 2,376,220.31	23,570,798.78	0.241513087	5,692,656.37	183,783,061.94
22	-	20,399.16	2,139.07	- 18,286,927.44	- 2,376,220.31	22,972,083.44	0.225713165	5,185,101.66	188,968,163.61
23	-	20,399.16	2,117.27	- 18,286,927.44	- 2,376,220.31	22,527,381.75	0.210946883	4,752,080.97	193,720,244.58
24	-	20,399.16	2,045.15	- 18,286,927.44	- 2,376,220.31	21,056,194.33	0.19714662	4,151,157.54	197,871,402.12
25	-	20,399.16	1,980.59	- 18,286,927.44	- 2,376,220.31	19,739,224.56	0.184249178	3,636,935.89	201,508,338.01
26	-	18,063.65	1,980.59	- 18,286,927.44	- 2,104,165.42	15,385,587.73	0.172195493	2,649,328.86	204,157,666.87
27	-	18,063.65	1,980.59	- 18,286,927.44	- 2,104,165.42	15,385,587.73	0.160930367	2,476,008.28	206,633,675.15
28	-	18,063.65	1,980.59	- 18,286,927.44	- 2,104,165.42	15,385,587.73	0.150402212	2,314,026.43	208,947,701.59
29	-	18,063.65	1,980.59	- 18,286,927.44	- 2,104,165.42	15,385,587.73	0.140562815	2,162,641.53	211,110,343.12
30	-	18,063.65	1,980.59	- 18,286,927.44	- 2,104,165.42	15,385,587.73	0.131367117	2,021,160.31	213,131,503.42
						627,141,426.48		**213,131,503.42**	-

Appendix D2 Oil Palm Carbon Revenue NPV Calculation

Year	Initial Cost - Carbon	Carbon Price	Carbon Storage model	Change of carbon storage	Carbon Revenue/(Cost)	Discounting Factor	PV Carbon Revenue	NPV Carbon Revenue
Notation	G_{Ao}	k	m	(Δm)	A_t	(1/1+α)^T		
Unit	Rp	Rp/Ton CO2 e	Ton CO2 e/Ha	Ton CO2 e/Ha	Rp/Ha	7%	Rp/Ha	Rp/Ha
0	- 39,296,544.00	337,231.53	5.0007	0	- 39,296,544.00	1	- 39,296,544.00	- 39,296,544.00
1	-	337,231.53	7.5456	2.5449	858,220.52	0.934579439	802,075.25	- 38,494,468.75
2	-	337,231.53	10.0905	2.5449	858,220.52	0.873438728	749,603.04	- 37,744,865.71
3	-	337,231.53	12.6354	2.5449	858,220.52	0.816297877	700,563.59	- 37,044,302.12
4	-	337,231.53	15.1803	2.5449	858,220.52	0.762895212	654,732.33	- 36,389,569.79
5	-	337,231.53	17.7252	2.5449	858,220.52	0.712986179	611,899.37	- 35,777,670.42
6	-	337,231.53	20.2701	2.5449	858,220.52	0.666342224	571,868.57	- 35,205,801.85
7	-	337,231.53	22.815	2.5449	858,220.52	0.622749742	534,456.61	- 34,671,345.24
8	-	337,231.53	25.3599	2.5449	858,220.52	0.582009105	499,492.16	- 34,171,853.09
9	-	337,231.53	27.9048	2.5449	858,220.52	0.543933743	466,815.10	- 33,705,037.99
10	-	337,231.53	30.4497	2.5449	858,220.52	0.508349292	436,275.79	- 33,268,762.19
11	-	337,231.53	32.9946	2.5449	858,220.52	0.475092796	407,734.39	- 32,861,027.81
12	-	337,231.53	35.5395	2.5449	858,220.52	0.444011959	381,060.17	- 32,479,967.63
13	-	337,231.53	38.0844	2.5449	858,220.52	0.414964448	356,131.00	- 32,123,836.63
14	-	337,231.53	40.6293	2.5449	858,220.52	0.387817241	332,832.71	- 31,791,003.91
15	-	337,231.53	43.1742	2.5449	858,220.52	0.36244602	311,058.61	- 31,479,945.30
16	-	337,231.53	45.7191	2.5449	858,220.52	0.338734598	290,708.98	- 31,189,236.32
17	-	337,231.53	48.264	2.5449	858,220.52	0.31657439	271,690.64	- 30,917,545.68
18	-	337,231.53	50.8089	2.5449	858,220.52	0.295863916	253,916.48	- 30,663,629.19
19	-	337,231.53	53.3538	2.5449	858,220.52	0.276508333	237,305.13	- 30,426,324.07
20	-	337,231.53	55.8987	2.5449	858,220.52	0.258419003	221,780.49	- 30,204,543.58
21	-	337,231.53	58.4436	2.5449	858,220.52	0.241513087	207,271.49	- 29,997,272.09
22	-	337,231.53	60.9885	2.5449	858,220.52	0.225713165	193,711.67	- 29,803,560.42
23	-	337,231.53	63.5334	2.5449	858,220.52	0.210946883	181,038.94	- 29,622,521.48
24	-	337,231.53	66.0783	2.5449	858,220.52	0.19714662	169,195.27	- 29,453,326.20
25	-	337,231.53	68.6232	2.5449	858,220.52	0.184249178	158,126.43	- 29,295,199.78
26	-	337,231.53	71.1681	2.5449	858,220.52	0.172195493	147,781.71	- 29,147,418.07
27	-	337,231.53	73.713	2.5449	858,220.52	0.160930367	138,113.74	- 29,009,304.33
28	-	337,231.53	76.2579	2.5449	858,220.52	0.150402212	129,078.27	- 28,880,226.06
29	-	337,231.53	78.8028	2.5449	858,220.52	0.140562815	120,633.89	- 28,759,592.17
30	-	337,231.53	81.3477	2.5449	858,220.52	0.131367117	112,741.96	- 28,646,850.21
					- 13,549,928.38		**- 28,646,850.21**	-

Appendix D3 Oil Palm Total Benefit NPV Calculation

Year	Sales Revenue/(Cost)	Carbon Revenue/(Cost)	Total Benefit	Discounting Factor	PV Benefit	NPV Benefit
Notation	V_t	A_t	G_t	(1/1+α)^T		
Unit	Rp/ha	Rp/Ha	Rp/Ha	7%	Rp/Ha	Rp/Ha
0	- 6,399,722.88	- 39,296,544.00	- 45,696,266.88	1	- 45,696,266.88	- 45,696,266.88
1	- 14,806,376.40	858,220.52	- 13,948,155.88	0.934579439	- 13,035,659.70	- 58,731,926.58
2	- 14,806,376.40	858,220.52	- 13,948,155.88	0.873438728	- 12,182,859.53	- 70,914,786.11
3	- 14,806,376.40	858,220.52	- 13,948,155.88	0.816297877	- 11,385,850.03	- 82,300,636.14
4	18,006,649.59	858,220.52	18,864,870.11	0.762895212	14,391,919.08	- 67,908,717.06
5	16,539,552.11	858,220.52	17,397,772.63	0.712986179	12,404,371.44	- 55,504,345.62
6	17,584,619.54	858,220.52	18,442,840.06	0.666342224	12,289,243.06	- 43,215,102.56
7	17,946,578.06	858,220.52	18,804,798.58	0.622749742	11,710,683.46	- 31,504,419.10
8	18,954,823.28	858,220.52	19,813,043.80	0.582009105	11,531,371.88	- 19,973,047.21
9	41,988,570.21	858,220.52	42,846,790.73	0.543933743	23,305,815.24	3,332,768.03
10	43,629,652.63	858,220.52	44,487,873.15	0.508349292	22,615,378.83	25,948,146.85
11	43,629,652.63	858,220.52	44,487,873.15	0.475092796	21,135,868.06	47,084,014.92
12	43,629,652.63	858,220.52	44,487,873.15	0.444011959	19,753,147.72	66,837,162.64
13	43,629,652.63	858,220.52	44,487,873.15	0.414964448	18,460,885.72	85,298,048.36
14	43,629,652.63	858,220.52	44,487,873.15	0.387817241	17,253,164.23	102,551,212.58
15	23,666,266.85	858,220.52	24,524,487.37	0.36244602	8,888,802.83	111,440,015.42
16	23,666,266.85	858,220.52	24,524,487.37	0.338734598	8,307,292.37	119,747,307.78
17	23,666,266.85	858,220.52	24,524,487.37	0.31657439	7,763,824.64	127,511,132.42
18	23,666,266.85	858,220.52	24,524,487.37	0.295863916	7,255,910.88	134,767,043.30
19	23,666,266.85	858,220.52	24,524,487.37	0.276508333	6,781,225.12	141,548,268.42
20	23,666,266.85	858,220.52	24,524,487.37	0.258419003	6,337,593.57	147,885,861.99
21	23,570,798.78	858,220.52	24,429,019.30	0.241513087	5,899,927.86	153,785,789.85
22	22,972,083.44	858,220.52	23,830,303.96	0.225713165	5,378,813.33	159,164,603.19
23	22,527,381.75	858,220.52	23,385,602.27	0.210946883	4,933,119.91	164,097,723.10
24	21,056,194.33	858,220.52	21,914,414.85	0.19714662	4,320,352.82	168,418,075.91
25	19,739,224.56	858,220.52	20,597,445.08	0.184249178	3,795,062.32	172,213,138.23
26	15,385,587.73	858,220.52	16,243,808.25	0.172195493	2,797,110.57	175,010,248.80
27	15,385,587.73	858,220.52	16,243,808.25	0.160930367	2,614,122.03	177,624,370.83
28	15,385,587.73	858,220.52	16,243,808.25	0.150402212	2,443,104.70	180,067,475.53
29	15,385,587.73	858,220.52	16,243,808.25	0.140562815	2,283,275.42	182,350,750.95
30	15,385,587.73	858,220.52	16,243,808.25	112,741.96	2,133,902.26	184,484,653.21
	627,141,426.48	**- 13,549,928.38**	**613,591,498.10**		**184,484,653.21**	

Appendix E1 Rubber Sales Revenue NPV Calculation

Year	Initial Cost - Sales	Quantity sold	Market Price	Fixed Cost	Variable Cost	Sales Revenue/(Cost)	Discounting Factor	PV Sales Revenue	NPV Sales Revenue
Notation	G_{Vo}	q	p	c		V_t	(1/1+α)^T		
Unit	Rp	Kg/ha	Rp/Kg	Rp/ha	Rp/ha	Rp/ha	7%	Rp/Ha	Rp/Ha
0	- 6,399,722.88	-	20,911.38	- 2,540,240.88	-	- 8,939,963.76	1	- 8,939,963.76	- 8,939,963.76
1	-	-	20,911.38	- 14,357,273.04	-	- 14,357,273.04	0.934579439	- 13,418,012.19	- 22,357,975.95
2	-	-	20,911.38	- 6,497,964.24	-	- 6,497,964.24	0.873438728	- 5,675,573.62	- 28,033,549.57
3	-	-	20,911.38	- 6,343,584.96	-	- 6,343,584.96	0.816297877	- 5,178,254.93	- 33,211,804.50
4	-	-	20,911.38	- 6,343,584.96	-	- 6,343,584.96	0.762895212	- 4,839,490.59	- 38,051,295.10
5	-	-	20,911.38	- 6,343,584.96	-	- 6,343,584.96	0.712986179	- 4,522,888.40	- 42,574,183.50
6	-	1,070.00	20,911.38	- 6,511,998.72	-	15,863,172.74	0.666342224	10,570,301.80	- 32,003,881.70
7	-	1,740.00	20,911.38	- 6,511,998.72	-	29,873,794.13	0.622749742	18,603,897.58	- 13,399,984.12
8	-	1,930.00	20,911.38	- 6,511,998.72	-	33,846,955.42	0.582009105	19,699,236.21	6,299,252.10
9	-	2,340.00	20,911.38	- 6,511,998.72	-	42,420,619.25	0.543933743	23,074,006.19	29,373,258.29
10	-	2,520.00	20,911.38	- 6,511,998.72	-	46,184,666.78	0.508349292	23,477,942.67	52,851,200.95
11	-	1,680.00	20,911.38	- 6,511,998.72	-	28,619,111.62	0.475092796	13,596,733.77	66,447,934.72
12	-	1,680.00	20,911.38	- 6,511,998.72	-	28,619,111.62	0.444011959	12,707,227.82	79,155,162.54
13	-	1,930.00	20,911.38	- 6,511,998.72	-	33,846,955.42	0.414964448	14,045,283.17	93,200,445.71
14	-	2,100.00	20,911.38	- 6,511,998.72	-	37,401,889.20	0.387817241	14,505,097.48	107,705,543.19
15	-	2,180.00	20,911.38	- 6,511,998.72	-	39,074,799.22	0.36244602	14,162,505.44	121,868,048.63
16	-	1,960.00	20,911.38	- 6,511,998.72	-	34,474,296.67	0.338734598	11,677,637.02	133,545,685.65
17	-	1,960.00	20,911.38	- 6,511,998.72	-	34,474,296.67	0.31657439	10,913,679.46	144,459,365.11
18	-	1,680.00	20,911.38	- 6,511,998.72	-	28,619,111.62	0.295863916	8,467,362.44	152,926,727.55
19	-	1,680.00	20,911.38	- 6,511,998.72	-	28,619,111.62	0.276508333	7,913,422.85	160,840,150.40
20	-	2,100.00	20,911.38	- 6,511,998.72	-	37,401,889.20	0.258419003	9,665,358.91	170,505,509.31
21	-	1,890.00	20,911.38	- 6,511,998.72	-	33,010,500.41	0.241513087	7,972,467.85	178,477,977.15
22	-	1,680.00	20,911.38	- 6,511,998.72	-	28,619,111.62	0.225713165	6,459,710.27	184,937,687.42
23	-	1,470.00	20,911.38	- 6,511,998.72	-	24,227,722.82	0.210946883	5,110,762.62	190,048,450.04
24	-	1,470.00	20,911.38	- 6,511,998.72	-	24,227,722.82	0.19714662	4,776,413.66	194,824,863.71
25	-	1,890.00	20,911.38	- 6,511,998.72	-	33,010,500.41	0.184249178	6,082,157.55	200,907,021.26
26	-	1,690.00	20,911.38	- 6,511,998.72	-	28,828,225.37	0.172195493	4,964,090.48	205,871,111.74
27	-	1,470.00	20,911.38	- 6,511,998.72	-	24,227,722.82	0.160930367	3,898,976.33	209,770,088.07
28	-	1,260.00	20,911.38	- 6,511,998.72	-	19,836,334.03	0.150402212	2,983,428.52	212,753,516.59
29	-	1,050.00	20,911.38	- 6,511,998.72	-	15,444,945.24	0.140562815	2,170,984.99	214,924,501.58
30	-	840.00	20,911.38	- 6,511,998.72	-	11,053,556.45	0.131367117	1,452,073.84	216,376,575.42
						693,000,167.23		**216,376,575.42**	-

Appendix E2 Rubber Carbon Revenue NPV Calculation

Year	**Initial Cost - Carbon**	**Carbon Price**	**Carbon Storage model**	**Change of carbon storage**	**Carbon Revenue/(Cost)**	**Discounting Factor**	**PV Carbon Revenue**	**NPV Carbon Revenue**
Notation	G_{A0}	k	m	(Δm)	A_t	$(1/1+\alpha)^T$		
Unit	Rp	Rp/Ton CO2 e	Ton CO2 e/Ha	Ton CO2 e/Ha	Rp/Ha	7%	Rp/Ha	Rp/Ha
0	- 39,296,544.00	337,231.53	- 31.65	0	- 39,296,544.00	1	- 39,296,544.00	- 39,296,544.00
1	-	337,231.53	- 25.53	6.12	2,063,856.96	0.934579439	1,928,838.28	- 37,367,705.72
2	-	337,231.53	- 19.54	5.992	2,020,691.33	0.873438728	1,764,950.06	- 35,602,755.65
3	-	337,231.53	- 13.68	5.864	1,977,525.69	0.816297877	1,614,250.02	- 33,988,505.63
4	-	337,231.53	- 7.94	5.736	1,934,360.06	0.762895212	1,475,714.03	- 32,512,791.60
5	-	337,231.53	- 2.33	5.608	1,891,194.42	0.712986179	1,348,395.48	- 31,164,396.12
6	-	337,231.53	3.15	5.48	1,848,028.78	0.666342224	1,231,419.61	- 29,932,976.51
7	-	337,231.53	8.50	5.352	1,804,863.15	0.622749742	1,123,978.06	- 28,808,998.45
8	-	337,231.53	13.72	5.224	1,761,697.51	0.582009105	1,025,323.99	- 27,783,674.46
9	-	337,231.53	18.82	5.096	1,718,531.88	0.543933743	934,767.48	- 26,848,906.98
10	-	337,231.53	23.79	4.968	1,675,366.24	0.508349292	851,671.24	- 25,997,235.74
11	-	337,231.53	28.63	4.84	1,632,200.61	0.475092796	775,446.75	- 25,221,788.99
12	-	337,231.53	33.34	4.712	1,589,034.97	0.444011959	705,550.53	- 24,516,238.46
13	-	337,231.53	37.92	4.584	1,545,869.33	0.414964448	641,480.81	- 23,874,757.65
14	-	337,231.53	42.38	4.456	1,502,703.70	0.387817241	582,774.40	- 23,291,983.24
15	-	337,231.53	46.71	4.328	1,459,538.06	0.36244602	529,003.76	- 22,762,979.48
16	-	337,231.53	50.91	4.2	1,416,372.43	0.338734598	479,774.34	- 22,283,205.14
17	-	337,231.53	54.98	4.072	1,373,206.79	0.31657439	434,722.10	- 21,848,483.04
18	-	337,231.53	58.92	3.944	1,330,041.15	0.295863916	393,511.18	- 21,454,971.85
19	-	337,231.53	62.74	3.816	1,286,875.52	0.276508333	355,831.80	- 21,099,140.05
20	-	337,231.53	66.43	3.688	1,243,709.88	0.258419003	321,398.27	- 20,777,741.78
21	-	337,231.53	69.99	3.56	1,200,544.25	0.241513087	289,947.15	- 20,487,794.63
22	-	337,231.53	73.42	3.432	1,157,378.61	0.225713165	261,235.59	- 20,226,559.04
23	-	337,231.53	76.72	3.304	1,114,212.98	0.210946883	235,039.75	- 19,991,519.29
24	-	337,231.53	79.90	3.176	1,071,047.34	0.19714662	211,153.36	- 19,780,365.92
25	-	337,231.53	82.95	3.048	1,027,881.70	0.184249178	189,386.36	- 19,590,979.57
26	-	337,231.53	85.87	2.92	984,716.07	0.172195493	169,563.67	- 19,421,415.90
27	-	337,231.53	88.66	2.792	941,550.43	0.160930367	151,524.06	- 19,269,891.84
28	-	337,231.53	91.32	2.664	898,384.80	0.150402212	135,119.06	- 19,134,772.78
29	-	337,231.53	93.86	2.536	855,219.16	0.140562815	120,212.01	- 19,014,560.77
30	-	337,231.53	96.27	2.408	812,053.52	0.131367117	106,677.13	- 18,907,883.64
					3,842,113.32		**- 18,907,883.64**	-

Appendix E3 Rubber Total Benefit NPV Calculation

Year	Sales Revenue/(Cost)	Carbon Revenue/(Cost)	Total Benefit	Discounting Factor	PV Benefit	NPV Benefit
Notation	V_t	A_t	G_t	(1/1+α)^T		
Unit	Rp/ha	Rp/Ha	Rp/Ha	7%	Rp/Ha	Rp/Ha
0	- 8,939,963.76	- 39,296,544.00	- 48,236,507.76	1	- 48,236,507.76	- 48,236,507.76
1	- 14,357,273.04	2,063,856.96	- 12,293,416.08	0.934579439	- 11,489,173.90	- 59,725,681.66
2	- 6,497,964.24	2,020,691.33	- 4,477,272.91	0.873438728	- 3,910,623.56	- 63,636,305.22
3	- 6,343,584.96	1,977,525.69	- 4,366,059.27	0.816297877	- 3,564,004.91	- 67,200,310.13
4	- 6,343,584.96	1,934,360.06	- 4,409,224.90	0.762895212	- 3,363,776.57	- 70,564,086.70
5	- 6,343,584.96	1,891,194.42	- 4,452,390.54	0.712986179	- 3,174,492.92	- 73,738,579.62
6	15,863,172.74	1,848,028.78	17,711,201.53	0.666342224	11,801,721.41	- 61,936,858.21
7	29,873,794.13	1,804,863.15	31,678,657.28	0.622749742	19,727,875.64	- 42,208,982.57
8	33,846,955.42	1,761,697.51	35,608,652.93	0.582009105	20,724,560.21	- 21,484,422.36
9	42,420,619.25	1,718,531.88	44,139,151.12	0.543933743	24,008,773.67	2,524,351.31
10	46,184,666.78	1,675,366.24	47,860,033.03	0.508349292	24,329,613.91	26,853,965.22
11	28,619,111.62	1,632,200.61	30,251,312.22	0.475092796	14,372,180.52	41,226,145.73
12	28,619,111.62	1,589,034.97	30,208,146.59	0.444011959	13,412,778.35	54,638,924.08
13	33,846,955.42	1,545,869.33	35,392,824.75	0.414964448	14,686,763.98	69,325,688.06
14	37,401,889.20	1,502,703.70	38,904,592.90	0.387817241	15,087,871.88	84,413,559.95
15	39,074,799.22	1,459,538.06	40,534,337.28	0.36244602	14,691,509.21	99,105,069.15
16	34,474,296.67	1,416,372.43	35,890,669.10	0.338734598	12,157,411.36	111,262,480.51
17	34,474,296.67	1,373,206.79	35,847,503.46	0.31657439	11,348,401.56	122,610,882.07
18	28,619,111.62	1,330,041.15	29,949,152.77	0.295863916	8,860,873.63	131,471,755.70
19	28,619,111.62	1,286,875.52	29,905,987.13	0.276508333	8,269,254.65	139,741,010.35
20	37,401,889.20	1,243,709.88	38,645,599.08	0.258419003	9,986,757.18	149,727,767.53
21	33,010,500.41	1,200,544.25	34,211,044.65	0.241513087	8,262,415.00	157,990,182.52
22	28,619,111.62	1,157,378.61	29,776,490.23	0.225713165	6,720,945.86	164,711,128.38
23	24,227,722.82	1,114,212.98	25,341,935.80	0.210946883	5,345,802.37	170,056,930.75
24	24,227,722.82	1,071,047.34	25,298,770.16	0.19714662	4,987,567.03	175,044,497.78
25	33,010,500.41	1,027,881.70	34,038,382.11	0.184249178	6,271,543.91	181,316,041.69
26	28,828,225.37	984,716.07	29,812,941.44	0.172195493	5,133,654.15	186,449,695.84
27	24,227,722.82	941,550.43	25,169,273.26	0.160930367	4,050,500.39	190,500,196.23
28	19,836,334.03	898,384.80	20,734,718.83	0.150402212	3,118,547.59	193,618,743.81
29	15,444,945.24	855,219.16	16,300,164.40	0.140562815	2,291,197.00	195,909,940.81
30	11,053,556.45	812,053.52	11,865,609.97	0.131367117	1,558,750.98	197,468,691.79
	693,000,167.23	**3,842,113.32**	**696,842,280.55**		**197,468,691.79**	-

Appendix F1 Cocoa Sales Revenue NPV Calculation

Year	Initial Cost - Sales	Quantity sold	Market Price	Fixed Cost	Variable Cost	Sales Revenue/(Cost)	Discounting Factor	PV Sales Revenue	NPV Sales Revenue
Notation	G_{Vo}	q	p	c		V_t	(1/1+α)^T		
Unit	Rp	Kg/ha	Rp/Kg	Rp/ha	Rp/ha	Rp/ha	7%	Rp/Ha	Rp/Ha
0	- 6,399,722.88	-	29,696.96	-21,828,879	-	- 28,228,601.88	1	- 28,228,601.88	- 28,228,601.88
1	-	0.14	29,696.96	-1,758,221	-	- 1,754,153.43	0.934579439	- 1,639,395.73	- 29,867,997.61
2	-	1.77	29,696.96	-1,758,221	-	- 1,705,668.84	0.873438728	- 1,489,797.22	- 31,357,794.83
3	-	7.38	29,696.96	-1,758,221	-	- 1,539,085.65	0.816297877	- 1,256,352.35	- 32,614,147.18
4	-	19.37	29,696.96	-1,758,221	-	- 1,183,107.27	0.762895212	- 902,586.87	- 33,516,734.06
5	-	39.44	29,696.96	-1,758,221	-	- 587,066.72	0.712986179	- 418,570.46	- 33,935,304.51
6	-	68.40	29,696.96	-1,758,221	-	273,119.39	0.666342224	181,990.98	- 33,753,313.53
7	-	106.21	29,696.96	-1,758,221	-	1,395,749.67	0.622749742	869,202.75	- 32,884,110.78
8	-	152.06	29,696.96	-1,758,221	-	2,757,541.68	0.582009105	1,604,914.36	- 31,279,196.42
9	-	204.65	29,696.96	-1,758,221	-	4,319,192.58	0.543933743	2,349,354.58	- 28,929,841.83
10	-	262.29	29,696.96	-1,758,221	-	6,031,082.10	0.508349292	3,065,896.31	- 25,863,945.52
11	-	323.15	29,696.96	-1,758,221	-	7,838,444.66	0.475092796	3,723,988.59	- 22,139,956.92
12	-	385.36	29,696.96	-1,758,221	-	9,685,685.84	0.444011959	4,300,560.34	- 17,839,396.58
13	-	447.12	29,696.96	-1,758,221	-	11,519,736.35	0.414964448	4,780,281.03	- 13,059,115.55
14	-	506.81	29,696.96	-1,758,221	-	13,292,467.79	0.387817241	5,155,048.18	- 7,904,067.36
15	-	563.04	29,696.96	-1,758,221	-	14,962,266.01	0.36244602	5,423,013.76	- 2,481,053.60
16	-	614.65	29,696.96	-1,758,221	-	16,494,892.37	0.338734598	5,587,390.73	3,106,337.13
17	-	660.74	29,696.96	-1,758,221	-	17,863,772.40	0.31657439	5,655,212.86	8,761,549.99
18	-	700.68	29,696.96	-1,758,221	-	19,049,846.54	0.295863916	5,636,162.20	14,397,712.19
19	-	734.06	29,696.96	-1,758,221	-	20,041,104.33	0.276508333	5,541,532.35	19,939,244.54
20	-	760.69	29,696.96	-1,758,221	-	20,831,906.20	0.258419003	5,383,360.43	25,322,604.97
21	-	780.56	29,696.96	-1,758,221	-	21,422,179.06	0.241513087	5,173,736.59	30,496,341.56
22	-	793.84	29,696.96	-1,758,221	-	21,816,553.85	0.225713165	4,924,283.42	35,420,624.98
23	-	800.81	29,696.96	-1,758,221	-	22,023,497.53	0.210946883	4,645,788.17	40,066,413.15
24	-	801.86	29,696.96	-1,758,221	-	22,054,477.79	0.19714662	4,347,965.75	44,414,378.90
25	-	797.44	29,696.96	-1,758,221	-	21,923,186.85	0.184249178	4,039,329.15	48,453,708.04
26	-	788.06	29,696.96	-1,758,221	-	21,644,841.38	0.172195493	3,727,144.13	52,180,852.18
27	-	774.28	29,696.96	-1,758,221	-	21,235,567.50	0.160930367	3,417,447.68	55,598,299.85
28	-	756.65	29,696.96	-1,758,221	-	20,711,874.21	0.150402212	3,115,111.70	58,713,411.56
29	-	735.71	29,696.96	-1,758,221	-	20,090,214.16	0.140562815	2,823,937.06	61,537,348.62
30	-	712.02	29,696.96	-1,758,221	-	19,386,627.40	0.131367117	2,546,765.35	64,084,113.97
						343,668,143.84		**64,084,113.97**	-

Appendix F2 Cocoa Carbon Revenue NPV Calculation

Year	**Initial Cost - Carbon**	**Carbon Price**	**Carbon Storage model**	**Change of carbon storage**	**Carbon Revenue/(Cost)**	**Discounting Factor**	**PV Carbon Revenue**	**NPV Carbon Revenue**
Notation	G_{Ao}	k	m	(Δm)	A_t	(1/1+α)^T		
Unit	Rp	Rp/Ton CO2 e	Ton CO2 e/Ha	Ton CO2 e/Ha	Rp/Ha	7%	Rp/Ha	Rp/Ha
0	- 39,296,544.00	337,231.53	3.5548	0	- 39,296,544.00	1	- 39,296,544.00	- 39,296,544.00
1	-	337,231.53	5.622	2.0672	697,125.02	0.934579439	651,518.71	- 38,645,025.29
2	-	337,231.53	7.6892	2.0672	697,125.02	0.873438728	608,895.99	- 38,036,129.30
3	-	337,231.53	9.7564	2.0672	697,125.02	0.816297877	569,061.67	- 37,467,067.63
4	-	337,231.53	11.8236	2.0672	697,125.02	0.762895212	531,833.34	- 36,935,234.29
5	-	337,231.53	13.8908	2.0672	697,125.02	0.712986179	497,040.50	- 36,438,193.79
6	-	337,231.53	15.958	2.0672	697,125.02	0.666342224	464,523.84	- 35,973,669.95
7	-	337,231.53	18.0252	2.0672	697,125.02	0.622749742	434,134.43	- 35,539,535.52
8	-	337,231.53	20.0924	2.0672	697,125.02	0.582009105	405,733.11	- 35,133,802.42
9	-	337,231.53	22.1596	2.0672	697,125.02	0.543933743	379,189.82	- 34,754,612.60
10	-	337,231.53	24.2268	2.0672	697,125.02	0.508349292	354,383.01	- 34,400,229.59
11	-	337,231.53	26.294	2.0672	697,125.02	0.475092796	331,199.07	- 34,069,030.51
12	-	337,231.53	28.3612	2.0672	697,125.02	0.444011959	309,531.85	- 33,759,498.67
13	-	337,231.53	30.4284	2.0672	697,125.02	0.414964448	289,282.10	- 33,470,216.57
14	-	337,231.53	32.4956	2.0672	697,125.02	0.387817241	270,357.10	- 33,199,859.47
15	-	337,231.53	34.5628	2.0672	697,125.02	0.36244602	252,670.19	- 32,947,189.28
16	-	337,231.53	36.63	2.0672	697,125.02	0.338734598	236,140.36	- 32,711,048.91
17	-	337,231.53	38.6972	2.0672	697,125.02	0.31657439	220,691.93	- 32,490,356.99
18	-	337,231.53	40.7644	2.0672	697,125.02	0.295863916	206,254.14	- 32,284,102.85
19	-	337,231.53	42.8316	2.0672	697,125.02	0.276508333	192,760.88	- 32,091,341.97
20	-	337,231.53	44.8988	2.0672	697,125.02	0.258419003	180,150.35	- 31,911,191.62
21	-	337,231.53	46.966	2.0672	697,125.02	0.241513087	168,364.82	- 31,742,826.80
22	-	337,231.53	49.0332	2.0672	697,125.02	0.225713165	157,350.29	- 31,585,476.51
23	-	337,231.53	51.1004	2.0672	697,125.02	0.210946883	147,056.35	- 31,438,420.16
24	-	337,231.53	53.1676	2.0672	697,125.02	0.19714662	137,435.84	- 31,300,984.32
25	-	337,231.53	55.2348	2.0672	697,125.02	0.184249178	128,444.71	- 31,172,539.61
26	-	337,231.53	57.302	2.0672	697,125.02	0.172195493	120,041.79	- 31,052,497.82
27	-	337,231.53	59.3692	2.0672	697,125.02	0.160930367	112,188.59	- 30,940,309.24
28	-	337,231.53	61.4364	2.0672	697,125.02	0.150402212	104,849.15	- 30,835,460.09
29	-	337,231.53	63.5036	2.0672	697,125.02	0.140562815	97,989.86	- 30,737,470.24
30	-	337,231.53	65.5708	2.0672	697,125.02	0.131367117	91,579.30	- 30,645,890.93
					- 18,382,793.44		**- 30,645,890.93**	-

Appendix F3 Cocoa Total Benefit NPV Calculation

Year	Sales Revenue/(Cost)	Carbon Revenue/(Cost)	Total Benefit	Discounting Factor	PV Benefit	NPV Benefit
Notation	V_t	A_t	G_t	(1/1+α)^T		
Unit	Rp/ha	Rp/Ha	Rp/Ha	7%	Rp/Ha	Rp/Ha
0	- 28,228,601.88	- 39,296,544.00	- 67,525,145.88	1	- 67,525,145.88	- 67,525,145.88
1	- 1,754,153.43	697,125.02	- 1,057,028.42	0.934579439	- 987,877.02	- 68,513,022.90
2	- 1,705,668.84	697,125.02	- 1,008,543.82	0.873438728	- 880,901.23	- 69,393,924.13
3	- 1,539,085.65	697,125.02	- 841,960.63	0.816297877	- 687,290.67	- 70,081,214.81
4	- 1,183,107.27	697,125.02	- 485,982.25	0.762895212	- 370,753.54	- 70,451,968.34
5	- 587,066.72	697,125.02	110,058.30	0.712986179	78,470.05	- 70,373,498.30
6	273,119.39	697,125.02	970,244.41	0.666342224	646,514.82	- 69,726,983.48
7	1,395,749.67	697,125.02	2,092,874.69	0.622749742	1,303,337.17	- 68,423,646.31
8	2,757,541.68	697,125.02	3,454,666.70	0.582009105	2,010,647.47	- 66,412,998.83
9	4,319,192.58	697,125.02	5,016,317.60	0.543933743	2,728,544.41	- 63,684,454.43
10	6,031,082.10	697,125.02	6,728,207.11	0.508349292	3,420,279.32	- 60,264,175.10
11	7,838,444.66	697,125.02	8,535,569.68	0.475092796	4,055,187.67	- 56,208,987.43
12	9,685,685.84	697,125.02	10,382,810.85	0.444011959	4,610,092.19	- 51,598,895.24
13	11,519,736.35	697,125.02	12,216,861.37	0.414964448	5,069,563.13	- 46,529,332.11
14	13,292,467.79	697,125.02	13,989,592.80	0.387817241	5,425,405.28	- 41,103,926.83
15	14,962,266.01	697,125.02	15,659,391.03	0.36244602	5,675,683.95	- 35,428,242.88
16	16,494,892.37	697,125.02	17,192,017.39	0.338734598	5,823,531.10	- 29,604,711.79
17	17,863,772.40	697,125.02	18,560,897.42	0.31657439	5,875,904.79	- 23,728,807.00
18	19,049,846.54	697,125.02	19,746,971.56	0.295863916	5,842,416.34	- 17,886,390.66
19	20,041,104.33	697,125.02	20,738,229.35	0.276508333	5,734,293.23	- 12,152,097.43
20	20,831,906.20	697,125.02	21,529,031.22	0.258419003	5,563,510.78	- 6,588,586.65
21	21,422,179.06	697,125.02	22,119,304.08	0.241513087	5,342,101.40	- 1,246,485.25
22	21,816,553.85	697,125.02	22,513,678.87	0.225713165	5,081,633.72	3,835,148.47
23	22,023,497.53	697,125.02	22,720,622.55	0.210946883	4,792,844.52	8,627,992.99
24	22,054,477.79	697,125.02	22,751,602.81	0.19714662	4,485,401.59	13,113,394.58
25	21,923,186.85	697,125.02	22,620,311.87	0.184249178	4,167,773.86	17,281,168.43
26	21,644,841.38	697,125.02	22,341,966.40	0.172195493	3,847,185.92	21,128,354.35
27	21,235,567.50	697,125.02	21,932,692.52	0.160930367	3,529,636.26	24,657,990.62
28	20,711,874.21	697,125.02	21,408,999.23	0.150402212	3,219,960.85	27,877,951.47
29	20,090,214.16	697,125.02	20,787,339.18	0.140562815	2,921,926.92	30,799,878.39
30	19,386,627.40	697,125.02	20,083,752.42	0.131367117	2,638,344.66	33,438,223.04
	343,668,143.84	**- 18,382,793.44**	**325,285,350.41**		**33,438,223.04**	-